MINING ENGINEERING

JULY 1949

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•

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...reatment for Flotation

A MONTHLY PUBLICATION OF THE
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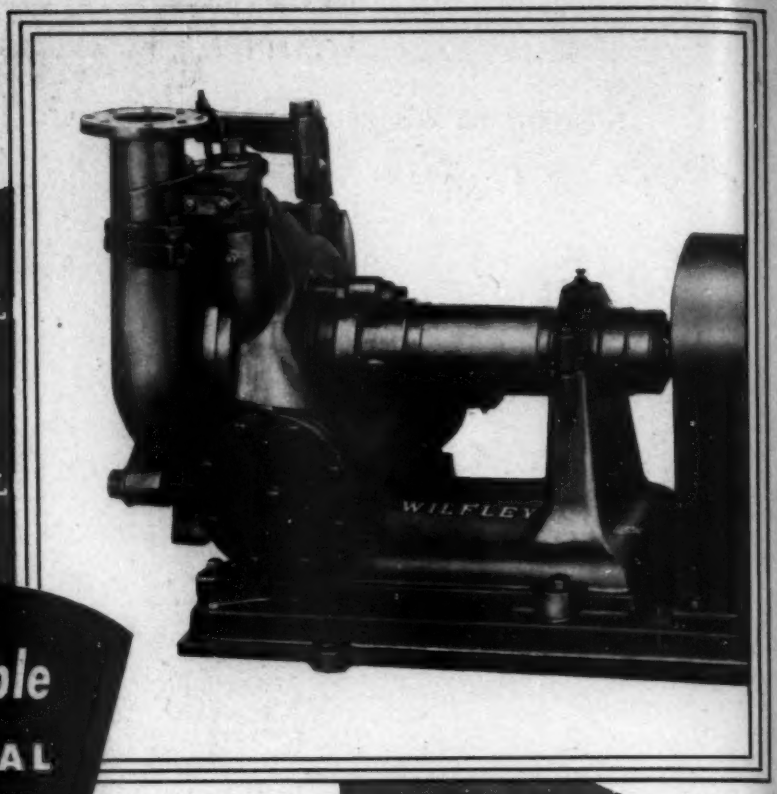

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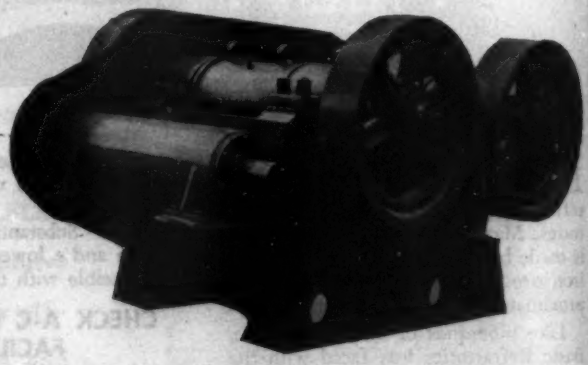
One of the latest additions to this line, the Twin Jaw crusher shown here, often does the work of both jaw and roll crusher in one operation. Type 4340 nickel-chromium-molybdenum steel shafts permit use of high-speed power units, with consequent lower total weight, and increased production.

This grade of steel, and Type 3140 nickel-chromium steel, meet exacting demands for high strength combined with good ductility, toughness and resistance to fatigue. Performance of these nickel alloy steels in heavy-duty crushers indicates how use of the right alloy steel assures substantial economies. Write for our recommendations regarding the best types of nickel steel for your equipment.



"Cedarapids" Twin Jaw crusher with nickel alloy steel eccentric and countershaft... made for primary crushing of rock... range in sizes that produce from 2 to 5 tons, up to 250 to 300 tons per hour.

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in which is incorporated Mining and Metallurgy, Mining Technology and Coal Technology

JULY 1949 VOLUME I, No. 7

Cover photo shows a geologist measuring the dip of a copper ore vein in Anaconda's Badger State mine. Courtesy K. I. Nesmith & Assoc.

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DEOXIDIZED COPPER 939	99.9 Copper, deoxidizer present	1083	1981	Oxy-acetylene welding of copper.
SILVER BEARING COPPER 110	99 Copper, 1 Silver	1078	1972	Oxy-acetylene welding of copper.
SILICON COPPER 943	99.75 Copper, .25 Silicon	1083	1981	Oxy-acetylene welding of copper, copper to steel.
TOBIN BRONZE* 481	59 Copper, .50 Tin, remainder Zinc	885	1625	Oxy-acetylene welding of steel, cast iron, copper and its alloys, nickel and its alloys.
ECONOMY BRONZE*	Copper, Zinc, Tin	885	1625	Oxy-acetylene welding of steel and cast iron, etc.
ANACONDA 997 (LOW FUMING)	Copper, Zinc, Tin, Iron, Manganese, Silicon	870	1598	Oxy-acetylene welding of steel, cast iron, copper and its alloys, nickel and its alloys. Bearing surfaces.
MANGANESE BRONZE 984	Copper, Zinc, Tin, Iron Manganese	870	1598	Oxy-acetylene welding of steel, cast iron, copper and its alloys, nickel and its alloys.
SUPER-NICKEL 826	70 Copper, 30 Nickel	1225	2237	Oxy-acetylene welding of Cupro-Nickel and steel.
EVERDUR 1010	96 Copper, 3 Silicon, 1 Manganese	1019	1866	Oxy-acetylene and carbon arc welding of Everdur, copper and copper alloys. Special applications to steel.
PHOSPHOR BRONZE 903	95.75 Copper, 4.00 Tin, .25 Phosphorus	1050	1922	Carbon arc welding of phosphor bronze and copper. Special applications to steel.
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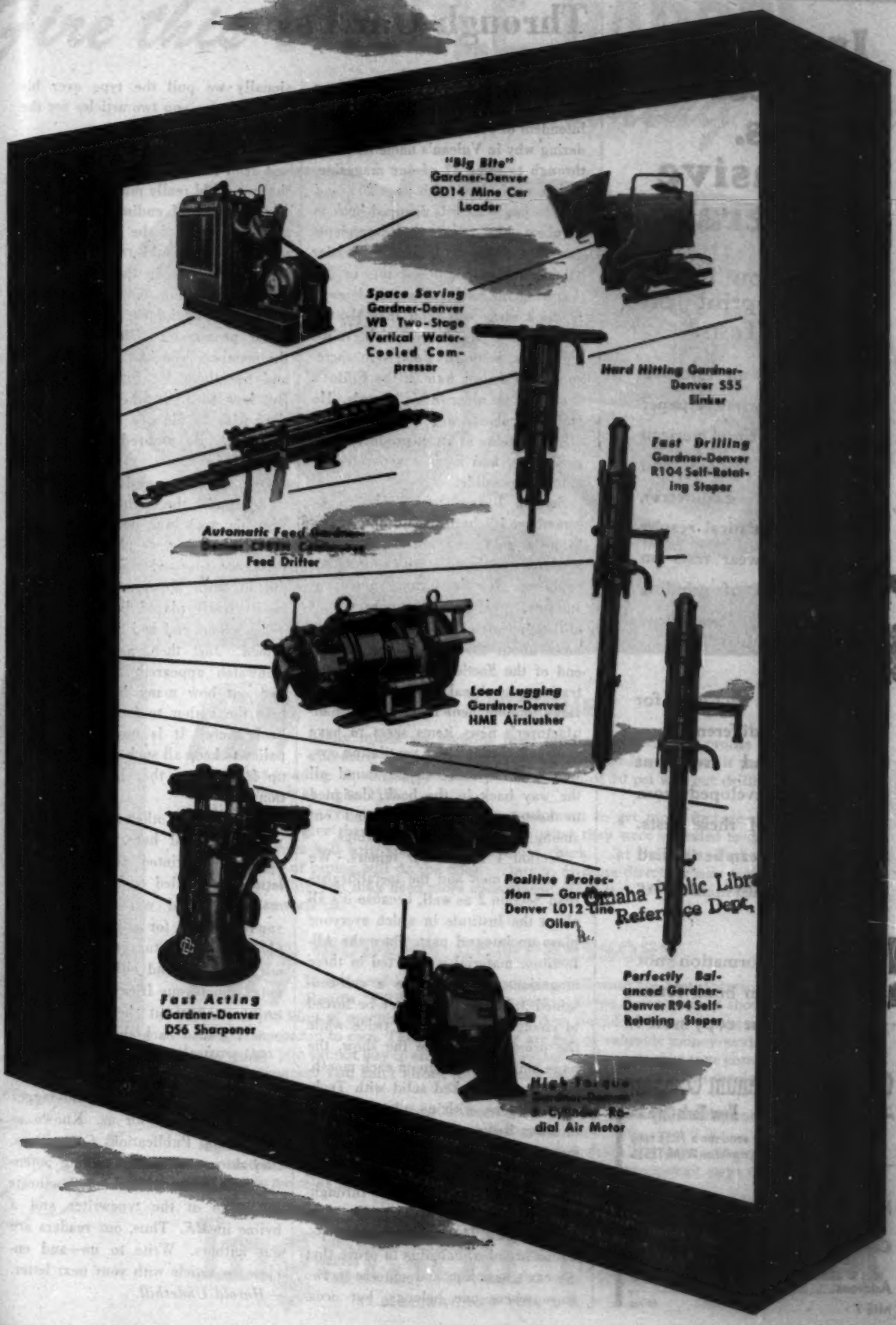
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Through Our Pages

At least once a month we get a letter from a harrassed mine superintendent or sun-baked geologist, wondering why in Vulcan's name he reads through to page 32 of our magazine, is then confronted with page 204, and sixteen pages later is dropped back to number 200. Such correspondents can lay claim to legitimate reader gripes, but as engineers, they're underrating the value of a rich deposit. A quick assay will show that MINING ENGINEERING has three rich veins, known as Sections. Each vein corresponds to a grey hair in the Editor's head, and an ulcer in his innards. He and his cohorts are trying to work all three veins at once, produce high-grade ore, and keep it separated as much as possible.

Section 1 (see table of contents, sometimes it's hard to find otherwise) is pure gold and meant for hard-working engineers with operating problems. It's the forum where consultants, professors, managers and mill superintendents gather to trade notes about the day's work. At the end of the Section, there's that frustrating page break, and the book reviews, employment notices, and manufacturer's news items seem to have vanished through the ventilating system. Actually, it can be found all the way back in the book, designed to keep you weaving in and out among our advertisers' offerings.

Section 1 is just for miners. We let the oil men and the metallurgists read Section 2 as well, because it's all about the Institute in which everyone plays an integral part. Since the All-Institute material is inserted in three magazines, it has to be a self-contained unit, lest the printer be forced to change page numbers twice while the presses roll. Like the show, the page numbers must go on each month. Section 3 is packed solid with Technical Papers, with no advertisements or short items added, and is plucked out at the end of the year for binding into Transactions volumes, so the page numbers must be consecutive throughout the year. That's the setup, pure and simple. The printer uses a peculiar brand of calculus to prove that we can't beat him and squeeze in two lines where one belongs, but occasionally we pull the type over his eyes and give you two articles for the price of one.

Stop looking at the page numbers and read the articles, and you'll find that we could really make it tough for you. Instead of ending each article on the bottom of the page, all nice and neat, we could take you for a sleigh ride back in the hills around the advertisements. Or the type could be squeezed tighter, and pictures made peanut-size. Then, there are the members who like to clip articles and file them for future reference. But how to do it when two articles they wish to file are lined up back to back? Be assured that we are working on it.

One author queried us, and quite calmly under the circumstances, as to why his work was not published in the March issue, as planned. Blushingly, we informed him that his work did in truth appear, but had been inadvertently placed back where the Transactions end and Section 1 is resumed. Just then, a cynic with a stopwatch appeared, and offered to find out how many hours it would take the author to locate his article back there. It is now our avowed policy to keep all such feature articles up front where they belong, in Section 1.

Section 1 has other fine features as well. Up front here, you may find that we've printed that interesting letter you mailed to the Editor last month (or did you mail it?). If you're looking for a job, or an employee, you can turn to the back of our book and find either one. News notes about your friends in manufacturing, and about their latest products, are also back there.

Since our mother was scared by a Congressional committee, we'll admit that we have many cloak-and-dagger men out working for us. Known as Papers and Publications Committees, they do a good job of talking potential authors into forsaking flowsheets for a go at the typewriter and a byline in *ME*. Thus, our readers are our authors. Write to us—and enclose an article with your next letter. —*Harold Underhill.*

Fire this DOUBLE BARREL *at your mining costs*

1 FULL AIR PRESSURE

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for **concentration of old mill tailing prior to recovery of values by regrind and flotation of spiral concentrate.**

for **recovery of high iron, low silica concentrate from iron ore washer tailing.**

for **cleaning minus ¼ inch bituminous or anthracite coal.**

for **separation of fine phosphate rock from sand.**

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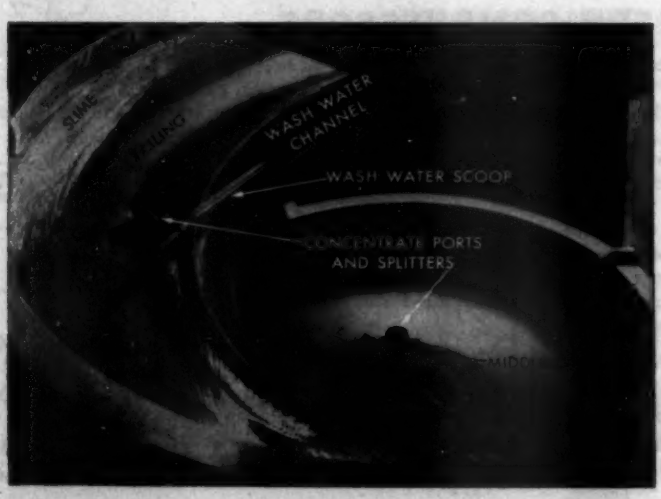
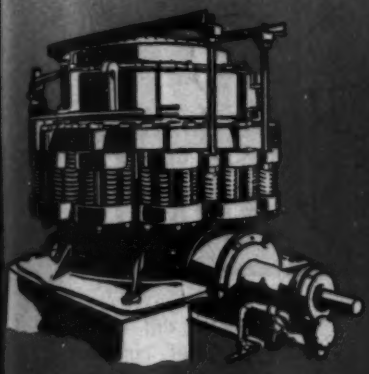


Closed circuit test unit including single spiral of full size. Results obtainable in a full size plant may be determined by tests of representative sample of approximately 200 lbs.

Concentrating action of spiral. Note wide black band of concentrate entering upper outlet, which is set for a wide cut, also narrow black band of middling entering lower outlet set for thin cut. In cleaning fine coal, refuse and middling are discharged from the concentrate ports and cleaned coal follows the path shown as tailing above.



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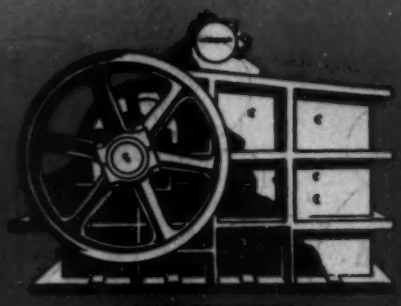

JAW CRUSHERS

GYRATORY CRUSHERS

Mining turns to NORDBERG

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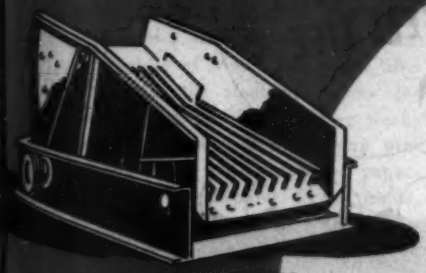

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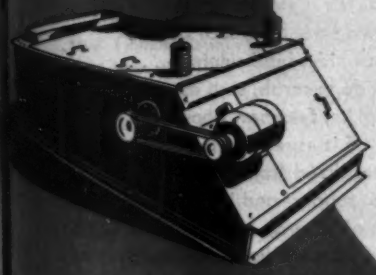

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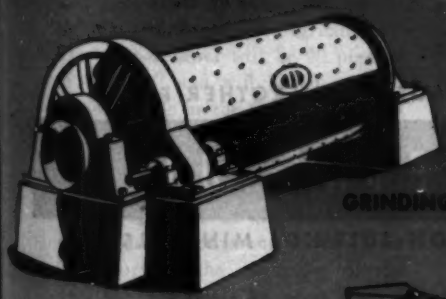

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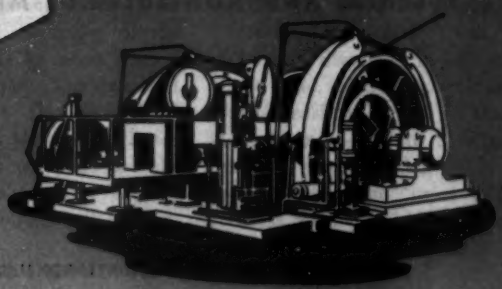

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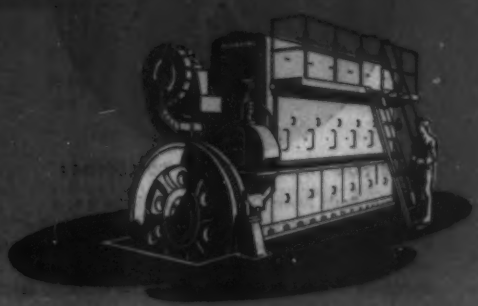

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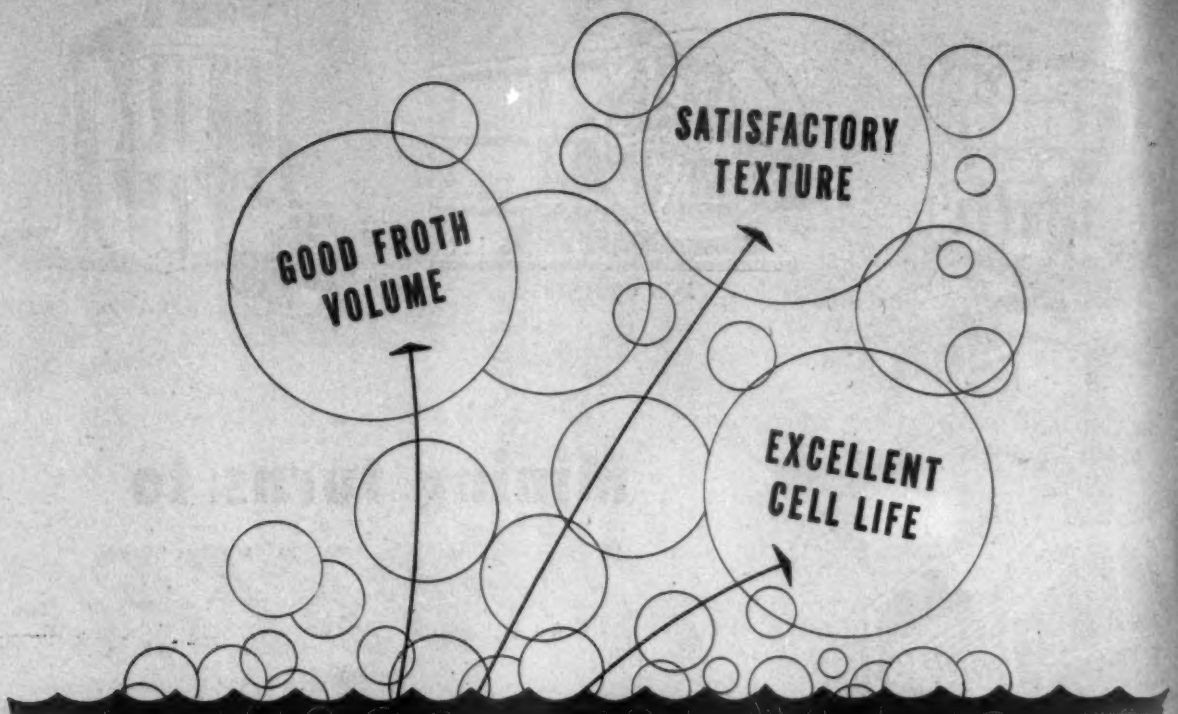

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MINING ENGINEERING

No Cause for Panic

As this is written, on Tuesday morning, June 14, *The New York Times* carries a head reading, "Market Touches New 5-year Low." Its curve of the daily average of fifty stocks has been headed downward on about a sixty-degree angle since the middle of May. The paper also notes that the steel index has declined again for the preceding week, and that ingots are now being produced at only 86.7 percent of capacity. (The cutoff point, as to profits, used to be about 60 percent we believe.) Copper, it says, has been reduced another half cent by a custom smelter, to 16½ cents; platinum $3 an ounce, to $69; and secondary remelt aluminum from ¾ to 1½ cents per pound. From Canada, it reports that Consolidated Mining and Smelting has declared an extra dividend of $3.50 a share in addition to the regular payment of $1.50, but that the "sharp decline in lead and zinc prices in the last three months will be reflected in reduced earnings." While metal prices are going down, we note a news item from Washington saying, "Arrangements for new price support programs for tobacco and peanuts were announced today by the Department of Agriculture." The support level will be 90 percent of "parity," and will be enjoyed by those who do as the Government tells them about production. Mr. Lewis has called a week's strike of all coal miners so he will be in a better bargaining position at the end of the month, and on page one of the *Times* is a story on the disruption of the coal industry likely to result from a breach between the Northern and Southern operators. Our own AIME member, Harry M. Moses, it indicates is being groomed to speak for the Northern operators, to do for industry what John L. is doing for the union.

This is merely a typical day's output of news of interest to the mineral industry. Only the petroleum industry seems to be neglected.

Our private reports from some of our more observant members indicate that many industrial leaders are getting panicky. They have long heard that Stalin is only waiting for a good depression in this country to start the world revolution, and they seem pretty sure that the time has come.

It is true that wartime and postwar levels of production and price have ended and that the drop in demand for mineral and other commodities has been sudden and severe. It is also true that it is difficult for industrial leaders, who have been enjoying a seller's market for going-on ten years, with a ready market for all that could be produced, at high prices, to become accustomed to times as they used to be. They throw up their hands in despair at the absence of demand as customers use up their inventories; at a price of 16½ cents for copper (11 cents ten years ago), 12 cents for lead (5 cents ten years ago), 9½ cents for zinc (5¾ a decade earlier), and 4.2 cents average for finished steel (2.7 ten years back). For years their main problem has been to find labor.

Especially hard hit is lead, for only a few months ago lead was 21½ cents a pound and the present level is but little more than half that, though in the five-year period preceding the war it did not average quite 5 cents. The situation was pretty thoroughly discussed at the meeting of the Lead Industries Association at Chicago early in April. At that time the opinion seemed to be that 21½ cents was really too high to last, and that a "wholesome" price would be 18 cents, which would be comparable, in profit-earning, to 6½ to 8 cents in 1945-46. "It might get as low as 14 cents, and most of the mines could still operate; but profits would be very unsatisfactory." There was talk of increased customs duty, and some form of subsidization, but a disinclination to accept the government control that the latter would involve. The drop in price was viewed as converting ore into waste at a rate far faster than even our most brilliant geologists, in their most optimistic moments of crystal gazing, could replace it.

Undeniably, present prices, or the even lower prices that are possible if not probable in the future, mean the vanishing point in profits for many producers, but there is always this marginal group. But long-established producers also are experiencing narrow, or complete extinguishment of profits, based on recent costs of operation. It is in reducing the latter factor that we think the best hope lies. With the cost of living index for the country as a whole at about 170 percent of the 1935-39 average, there would seem no reason why the cost of industrial operation should be 200 or 300 percent, as it has been for many mining companies. The hope of reducing costs seems much more likely to be realized than does price maintenance or increase. Labor must be told that wage rates must be lowered or no jobs at all will be available. Demand may be temporarily almost nonexistent, but it will return in good part when inventories get down to rock bottom. The ultimate consumer is not going to stop buying the things he needs.

Times are admittedly tough, but the old exhortation about keeping one's shirt on would appear to be particularly applicable now.

Photos courtesy Bureau of Mines

This is man, and nature, with man looming large in perspective. The N-T-U retorts (foreground) and shale storage bins of the Bureau of Mines' overshadow sheer cliffs of oil shale at Rifle, Colo., from which oil is being extracted.

Human Resourcefulness Key to Mineral Supplies

By MAX W. BALL • CONSULTANT, WASHINGTON, D. C.; MEMBER, AIME

Our ever-increasing use of minerals has been the outstanding fact in our American economic development. The rise in our standard of living in the past century is without equal in human history. Nowhere in time or place has the man who works lived so well, or the man who cannot work been so well cared for. We live in a new world, even the poorest of us, that our forebears of 1849 could not have dreamed.

That new world has come mainly from our use of minerals. Our per capita use of nonmineral products has grown too, but by only a modest amount. Food consumption per person has grown about 15 per cent in the past fifty years; lumber use per person has fallen 56 per cent and that of wood for fuel 65 per cent. Of all the products of field and forest, our use, per capita, may have increased by one fifth during the present century. In contrast, our per capita use of minerals has multiplied several times. Each of us uses 2½ times as much steel and 16½ times as much petroleum as our fathers used in 1900. In less than half a century our per capita consumption of all minerals has probably risen by 200 to 250 per cent.

Man once built with wood; today he builds mainly with brick and stone and steel. Once he traveled by the power of hay and oats; today he travels by the power of coal and oil. Rubber made from minerals is already better for some uses than rubber tapped from trees; before long it will be better for most and perhaps all uses. Even our ladies' graceful legs are clad in mineral fiber, where once animal or vegetable fiber would have covered them. Our high standard of living is a product of the machine. The machine is made of minerals. The machine is driven by minerals. The machine age is a mineral age.

Slightly condensed from an address at the University of New Hampshire, Durham, Oct. 8, 1948, at the installation of A. S. Adams as president.

is the machine age evil?

In some circles the fashion is to deride the machine age, to call it a sordid age, an age when men's souls are bound to the machine. As though the machine and not the man were master, as though man's spirit were more free before he had the machine to serve him.

That fashion is not new. An hour's ride from here, by grace of this machine age, is a body of gray-green water called Walden Pond. By Walden Pond, a hundred years ago, a young man built a hut, lived in it for two years, and emerged to praise the self-sufficient life and to decry industrialism, the use of the machine. The machine was evil, because it chained man to his work and made him dependent on the work of other men. If Thoreau was right, then our growing use of minerals is not a blessing but a curse.

But when Thoreau lived by Walden Pond, the typical workman walked to his job while night was still dark, worked through the day, quit and walked home when night was dark again. To make a scanty living, he drudged for 70 or 80 or 85 hours a week, every week in the year. Today's typical workman rides to and from his job in his own car. He drudges little. He makes a far more abundant living in about half the time. The rest of the time is his own. He has leisure and unused energy, instead of long hours and exhaustion.

A similar change has come to all of us, differing only in degree. Whether we use our leisure wisely or unwisely is beside the point. The machine has given it to us; we have a choice that our forebears lacked. If we fail to think as widely and as wisely as we should, if we fail to court beauty, if our spirits crawl instead of soar, the fault is with us, not with the machine. Industrialism, with its increased output per man, has given us each a golden age, if only we make it so.

Increased output per man, the making by each of more and more goods for other men to use: that is the meaning of industrialism. Under industrialism, each man helps to make goods for other men, instead of making goods solely for himself. The more he makes, the more other men may have.

industrialism improves living standard

That is the meaning that Thoreau missed, and that other men of cloistered vision miss today. Because part of the world is industrialized, millions of people live better than any people have ever lived before. Because more of the world is not yet industrialized, millions of people barely live, at the lowest level of subsistence. Because countries once industrialized have been deindustrialized by war, millions live more meanly than they used to live, poorer in body and in spirit. If less of the world were industrialized, millions now living could not live at all.

Potential overpopulation has two cures, one negative and one positive. The negative cure is to keep people from living, to kill them with war, famine, and disease. The positive cure is to produce more, so that more people may live on it. The choice is between the Four Horsemen of the Apocalypse and the benign genius of the machine. The high road of humanity and hope does not run through the valley of Walden Pond; it sweeps across the uplands toward more and more abundance for more and more people.

Tracing the course of industrialism from its inception, in resonant prose, Mr. Ball describes the part played by minerals in making industrial progress possible. Human resourcefulness dug our coal and drilled our oil wells so that we would have power to extract minerals from leaner ores and as these fuels become scarce and these minerals come from leaner ores, human ingenuity will develop new sources of energy to continue recovering the minerals we need. Here is a sound, convincing reply to those who think the United States is a have-not nation.

man's resourcefulness our hope

More and more abundance calls for more and more minerals: for more industrialization; for more machines; for more minerals to make and drive the machines. Without enough minerals the upward road may end, and life as we know it in the United States may end with it. How do we stand for minerals?

Someone has said recently that we have used more minerals in the past hundred years than in the entire previous span of human history; that nature can stand no such drain; and that presently civilization will stop for lack of minerals. I do not question the fact; I do question the conclusion.

We have been using minerals faster and faster since man chipped his first flint. Probably we have used more in a century than in the uncounted thousands of preceding years. We are using some minerals faster than we are finding them. Before long, perhaps, we shall have exhausted the easy sources of some minerals we now call irreplaceable. But will man's inventive genius lapse because lead or asbestos or tin is scarce? Will he lose his ingenuity because quartz crystals must be made instead of found? I see the end for some of our resources, but I see no end to man's resourcefulness.

If we are reckless, we may some day exhaust our ready supplies of oil, gas, zinc, graphite, and some other minerals. Other minerals we shall never exhaust, notably magnesium, silicon, nitrates, and salt. If we are careful in our use, we shall be a long, long time exhausting our world supply of still other minerals, such as coal, iron, molybdenum, potash, and phosphate. And we shall be poor, spiritless creatures if we do not replace the scarce with the plentiful when the need comes.

progress by replacement

Note that I say "replace" instead of "substitute." "Substitution" is a loaded word. It connotes using something inferior, or at best something just as good but no better. It is too close kin to *ersatz*. Man has not progressed by accepting substitutes; he has progressed by replacing something good by something better. And the something better, almost every time, has been something more plentiful.

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Max W. Ball—geologist, lawyer, economist, writer, petroleum engineer, and philosopher, all in one. The first step in the development of this divers personality was growing up in Colorado and being inspired to attend the School of Mines there. Then, while he was practicing geology in Washington, D. C., he also found time to study law at the National University. Executive positions with the Government and a few petroleum outfits followed, giving him the substance for "This Fascinating Oil Business." This book, as well as his many other writings, shows how realistically he appraises the petroleum industry for its worth in a modern world.

I suspect that 30,000 years ago some Cro-Magnon patriarch, squatting by a fire in the valley of the Garonne or the Loire, flung away his mammoth bone and said, "We are going to run short of flints to shape into tools and weapons." He was right. Some 250 centuries later enough flints could not have been found for tools and weapons; too many men needed them. Nevertheless, men had tools and weapons, better tools and better weapons than ever, and more of them. They were made of bronze and brass. Early Romans were worried about copper to make bronze and brass. The mines of Cyprus and of Rio Tinto in Spain were about to play out. By that time tools and weapons were made of iron, and again were better and more plentiful than before.

We still use much bronze and brass. We still make bronze with tin, and brass with zinc, and tin and zinc are growing scarce. But day before yesterday, as it were, we learned that we can make bronze without tin and brass without zinc, and that either bronze or brass can be replaced by another metal, or by a plastic, for almost any use. Today we make our tools and weapons of steel. It comes from iron ore, but is better than the iron that replaced bronze and brass. The machine age is built of and on it; nearly 95 per cent of the metal we use is steel.

recover metals by other means

Steel men are starting to wonder about our iron ore supply. We have used up most of the great high-grade ore bodies south of Lake Superior. We have cut heavily into our other high-grade deposits. Before many years, we shall have to import more iron ore or mine lower grade ore bodies.

We can get rich ore from Canada, Labrador, Cuba, or Venezuela, if we want to stand the development and transportation costs and revise the geography of our steel industry. Or we can run for many years on domestic ores somewhat leaner than those we have been using. In time we shall have to use still leaner ores, or import more ore from farther away.

Using leaner ores is nothing new. The mines of Cyprus and Rio Tinto, which the Romans feared were nearing exhaustion, are still producing copper, and a pound of Cyprian or Rio Tinto copper probably costs no more in wheat or labor in Rome today than it did in the time of the Tarquins. The ores are leaner, but mining and smelting are better.

Smelting a leaner ore, of copper or iron or any other metal, may call for new techniques; it also calls for more energy in the form of greater or longer heat. Technique we may take for granted; one man or group may miss it but some other will find it, when the need is great enough. The basic requirement is energy. We can make iron from any red earth or aluminum from any clay, if we use enough energy. With enough energy, cheap enough to use, our supply of metals is almost limitless.

sources of energy plentiful

Part of the energy we use has always come from the muscle power of man and beast. Little more than a century ago it was our chief source. We got it from slaves, from the physical labor of free men, and from horses and oxen. Today it is our least important source. The machine and the fuel that runs the machine have made it small in our total energy supply.

The rest of the energy we use today comes from water power, from coal, from oil, and from natural gas. Last year, in the United States 4 per cent came from water power, 50 per cent from coal, and 46 per cent from oil and gas.

About 83 per cent of our potential water power is still undeveloped, roughly 58,000,000 horsepower out of a possible total of 70,000,000. We should develop it as rapidly as we need it and as the price for it justifies. It is our one present form of energy of which our reserves do not shrink with use. Even when fully developed, however, it will supply only a small part of our energy needs, probably no more and perhaps less than the 4 per cent it supplies today.

Of coal we have plenty for a long time to come. Estimates of 4000 years' supply, at present rates of use, are probably several times too high. The coal may be in the ground, but we may not get it out. Much of it lies in beds too thin or too deep to mine by present methods. Before we need these thin, deep beds, some other form of energy will probably have made coal obsolete. Our best coals are those most suitable for coking, raising steam, and domestic use. They are not too plentiful, especially in beds easily mined and located near the larger markets. Nevertheless, if we need it, coal can supply us with a vast amount of energy for three or four or five hundred years.

We have plenty of natural gas for present markets, if we could get it to them. We have been finding it faster than we have been using it. When steel supply catches up with demand, and we can build gas lines as fast as we wish, the story may be different; we may use gas faster than we can find it.

A curious fact adds to this danger: Federal and state governments regulate the price of most gas from the pipe-line intake to the consumer's burner; prices for coal and oil, the competing fuels, are regulated only by the

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rule of the market place. In many places, gas is cheaper today than coal or oil, heat unit for heat unit. If this continues, only one thing can happen: the whole of our energy load will shift to gas, the supply of which is not big enough to carry it. The price of gas at the well is still unregulated, and field prices are going up. This may in time restore the competitive balance, and keep our gas reserves from premature depletion.

oil output increasing

Crude oil production in the United States is increasing. How long it will continue to increase I do not know. The output of old fields declines; new fields must be found to take their places. Our present fields are producing at their maximum efficient rate; they have no excess productive capacity. Demand continues to grow; already it is 75 per cent above 1938, the last peacetime year before World War II, and 11 per cent above the peak year of the war.

We are producing more oil than we have ever produced, but we are producing a little less than we are using. We are importing more oil than we are exporting, for the first time since the oil business started in 1859, except for a brief flood of Mexican oil after World War I. We must either find new fields faster, or depend more and more on foreign sources.

We shall find many new fields. Much oil remains to be found in the United States, perhaps as much as we have found already. The question is, how fast can we find it? We have found 55 billion barrels in 79 years, and probably found the easiest fields to discover. We need to find two billion barrels to keep pace with this year's consumption, and more and more each year hereafter. It stands to reason that we cannot keep it up forever. Some day, sooner or later, we shall fail to find oil as fast as we use it. We must not waste it, either in producing it or using it, lest we hasten that day.

People talk about running out of oil in ten years, or twelve, or some other number. We will never run out of oil in the United States. A well gives up its oil more and more slowly year by year, after it passes its first flush stage. We could not drain our present fields dry in 50 years, or 100, if we should try. But we will be short of oil from our own fields as soon as their productive capacity drops below our current needs. Whether temporarily or permanently, we are short of oil from our own fields now. That is why American oil men are so busy overseas.

oil prospects abroad dark

Geologically, overseas prospects are rosy. Oil is found in sedimentary rocks—rocks laid down under water as mud and ooze and sand, and hardened by time and pressure. Any large area of thick sedimentary rocks is a promising place to look for oil. The earth has many such areas. Some of them have proved highly productive, in Venezuela, Colombia, the East Indies, Mexico, Peru, and the Argentine. Others, less productive as yet, may develop great production. The Middle East and parts of Russia may prove the most productive of all. Still other promising areas have not been explored. If all the

A three-cu yd dipper loads a fifteen-ton Diesel truck at the Rifle mine of the Bureau of Mines, where large-scale equipment lowers the cost of digging oil-shale.

world—even all the non-Russian world—were open to free enterprise and free interchange of goods, we need fear no shortage of oil for many years.

Politically and practically, overseas prospects are rather gray. The dead hand of nationalization lies on areas of great promise. A certain country has some of the world's largest and most promising unexplored areas, but private enterprise, even the private enterprise of the country's own citizens, is not permitted to explore or develop. Instead of being another Venezuela or perhaps another Iran, the country has a single trifling oil field. Another country with a nationalized oil industry may have ten to fifteen billion barrels of undiscovered oil. To keep step with development in the United States, she should have drilled 200 times as many wells as she has drilled. Instead of having large volumes of oil to export, as she once did to her great profit, she has scarcely enough for her own needs. In certain other countries, including some of our good neighbors, the door is closed to outside capital.

nationalization of oil impracticable

Whatever success nationalized industry may achieve in other fields, it will not make a success of finding oil. It lacks the necessary diversity of judgment and the ability to take chances.

Finding oil is not an exact science. Using all the geologic knowledge it can muster, it must finally depend on trial and error. Even in the United States, with all our experience and geologic knowledge, only one exploratory well in five is productive; the other four are dry holes. Nearly every present field was overlooked or turned down by many men before someone decided to risk drilling it. Nearly every active oil geologist has located many more dry holes than producers. Government officials just cannot operate that way. No govern-

ment official would dare to take one long chance after another with public funds, or would last long if he did. I am an oil geologist and was a government official; I should know.

All this is hard to understand, for governments inclined to public operation. They think the business of finding and producing oil is *ipso facto* productive of huge profits. They think those dreamed-of profits should go to their own citizens instead of to foreigners and capitalists. They underrate the risk that must precede the profits. They underrate the value, and the scarcity, of the huge investments and concentrated experience that make the profits possible. They think, in short, that all they need is a loan to make their treasuries rich from the profits of oil development.

They turn their backs, therefore, on the wealth in dollars and know-how that oil companies are spending in other countries and on how much those countries are enriched thereby. They turn toward the loans from other treasuries to put or keep them in the oil business.

In countries where private capital is admitted, the outlook is better, but I should not call it good. The governments of such countries also tend to overlook the risk and see only the profit, to demand a greater and greater share of the returns. Some day, in some countries important to us, the government may take so much that the remaining profit will not be worth the risk. That will end their private exploration and development.

American oil men are a hardy race. They will keep on knocking on foreign doors, and will enter those that are opened, and once inside will invest huge sums on promises of fair play. But if through the years they find the doors still closed, or having once been admitted find themselves squeezed out, then we need expect little oil from imports.

synthetic liquid fuels imminent

In that case, and perhaps in any case, we shall turn increasingly to the development of synthetic liquid fuels. Petroleum products can be made from natural gas, oil shale, and coal. A commercial plant is already building to make synthetic gasoline from natural gas, but large-scale production from natural gas is unlikely; gas is too good a direct fuel and too much needed as such. Commercial production from oil shale seems just around the corner, and in the course of years it could grow to large volume. Production from coal is farther away, but not too far away to foresee.

Synthesis from coal and oil shale uses large amounts of heat, which again raises the question of energy. How much of the energy in coal, for example, can we afford to burn up to turn the rest into gasoline or fuel oil?

new sources of energy needed

Thus we complete a full circle. We start with the need for more processing energy, the energy to get more metals from leaner ores. We turn to water power and fuels, and we find ourselves talking again about processing energy, the energy to convert one kind of fuel into another kind that we want.

What man needs is obvious: he needs a new source of energy, huge, cheap, and adaptable. He has his finger tips on it already. By the time he really needs atomic energy, to make steel from twenty per cent iron ore, or to make aluminum from ordinary clay—by that time he will have it in his hand, ready to use as he will.

We think of atomic energy as limitless, but all we have released so far, or are likely to release for many years, comes from a metal. Some day, a few hundred years from now, uranium may become scarce. By that time, or perhaps long before, we may have learned to tap geothermal energy, or we may have harnessed solar energy. The sun supplies to the United States 1600 times as much heat energy as we now use. Man will never be short of energy unless he is short of ingenuity.

That man will have adequate energy and adequate minerals for the future gives us no warrant to be wasteful in the present. We may exhaust the old before we have the new. The change from old to new is not always easy or painless. A country or a continent may become poor while the world as a whole becomes rich. "Waste not, want not" is as good a motto for a people as for a person. We shall not want in the United States if we do not waste, and if we keep our ingenuity bright and our spirit free.

rate of progress accelerating

From wooden tool to flint, from flint to bronze, from bronze to iron, from iron to steel, perhaps some day from steel to magnesium or silicon. From wood to coal; from coal to oil and gas and water power; from these to atomic energy; from atomic energy, sooner or later, to solar and geothermal energy. What a record, and what a prospect! What a monument to the surging, restless, inventive spirit of man; replacing something he has with something better; lightening his burden of physical toil; doing less and less work with his brawn, more and more with his brain; using his brain to devise more things to raise his standard of living faster and faster.

Faster and faster. Much has been said about the accelerating rate of progress. It is worth more words than I shall give it. From wood to coal took somewhere between 50,000 and 200,000 years. From coal to oil took about 600 years. From oil to atomic fission took less than 80 years. If we study the last 150 years, the accelerating speed is still more striking: from the steam engine to the locomotive to the automobile to the airplane; from the telegraph and telephone to radio and television; from photography to the magic lantern to silent movies to talking movies to Technicolor.

In part this is a chain reaction: one invention suggests others, and these suggest still others, and thus on and on, in geometrical progression. The deeper explanation is even simpler: as man gives himself more and more time to think, he thinks of more and more things to better himself and his fellows.

This is the genius of the machine: it frees the creative minds of more and more men from the drudgery of making a living; frees them to create more and better things, to the benefit of their fellow men. So long as men have this freedom in increasing measure, we shall not run out of natural resources. Our greatest natural resource is man's resourcefulness.

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Government, labor and equipment shortage, hamper

Japan's Mineral Industry

By JOHN J. COLLINS • GEOLOGIST, U. S. GEOLOGICAL SURVEY, MEMBER, AIME

The plight of the Japanese mining business is pitiful. Coal mines were given the highest priority for all materials they needed, yet between the end of the war and June 1948, the government was obliged to subsidize them to the extent of 22 billion yen, this being the difference between the consumer's price and the producer's price.

Most of the metal mining companies have been operating at only one fifth to one third of war-time production rates, and financial losses have been terrific. The chief difficulties have been a plethora of office workers and a dearth of equipment, supplies, and miners. The principal material needs at metal mines are steel rails, cars, plates, nails, rubber hoses, and belting, to say nothing of modern core drills which are totally lacking. Until recently the great shortage was in coal; for lack of fuel the smelters and factories failed to produce the very metals and equipment now needed to operate the mines.

Nation-wide shortages have created a monstrous inflation of prices throughout all the economy, currently amounting to 200 times the prewar figures. For example, the price of copper ranged from 500 to 900 yen per metric ton for many years until 1937, but in mid-1948 producers were given 181,060 yen per metric ton. Paradoxically, inflation partly helps the mining companies. Their assets are revalued upward and indebtedness that would have been crushing before the war no longer is as critical. Paradoxical, too, is the new twist in prices for certain metals on the "black" market—they are *lower* than the government's official prices!

The reader may well wonder why a company cannot make money if the price of his product is advancing rapidly. The answer is that the prices of all important commodities are controlled by the government, and distribution is rationed. The miners and mining companies, among others, get supplies that are too little and too late; hence, their costs go up. But it takes the companies a long time to convince the government of the facts. By the time a new selling price is granted, rising costs have already exceeded it.

Labor has been caught in the general inflationary squeeze and has learned the power of the strike. The idea of a 40-hour week is a problem in a country needing a lot of work to make ends meet. Metal mine labor unions have been comparatively reasonable, but Communist organizers have caused trouble in the coal fields. This is the more critical because, with the exception of food, the coal shortage has been until recently the most critical shortage in postwar Japan.

The mining companies have had other headaches too. One of the major objectives of the Occupation was to destroy the Zaibatsu, the great family holding companies, by splitting them into small units; but the program was extended to cover non-Zaibatsu companies and, in fact, nearly all industry. The policy in June 1947, was to break some mining companies into as many as seven parts.

Proponents of the great breakup claimed they were furthering free enterprise and democracy. Opponents claimed the breakup of the mining companies would weaken the industry until it was a pushover for socialism. Certain it is that once the mining companies are divorced from their Zaibatsu holding companies, they become weak little concerns, on the verge of bankruptcy. Meanwhile, management is still waiting for final decisions on their organizational setups

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before attempting any major reconstruction of their plants and properties.

Management itself has suffered directly. In the endeavor to eliminate Zaibatsu and military alliances, all men who had policy-making positions in big companies during the war have been removed from their business offices. This sudden withdrawal of the experienced executives affected a dozen mining companies, comparable to removing all the generals from an army.

Japan's resources

Coal is by far the major product of the Japanese mineral industry. If current coke experiments are successful, Japan could be self-sufficient in solid fuels on the basis of the stringent economy she is likely to have for many years. Until the end of World War II, Japan imported coking coal and, in effect, paid for it with exports of noncoking coal.

For centuries copper has been Japan's most valuable metal product, but since World War I the country's copper trade has alternated between an exporting and importing position, depending on business conditions. In the middle 1930's the revaluation of gold placed that precious metal in first place temporarily, but most of the gold produced is a by-product of copper refining.

Sulphur and pyrite come next, judged by their importance to Japan's mineral economy as a likely source of foreign exchange. Before the war sulphur constituted the major exportable mineral product of Japan, after coal. Zinc follows sulphur and pyrite and has generally been an exportable commodity. Lead occurs with zinc in the Japanese deposits, but in a low ratio, requiring large imports to meet industrial needs. Other important commodities in Japan's mineral output are low-price, large-tonnage materials, such as go into cement.

Domestic iron and oil rank with pyrite, sulphur, and zinc in dollar value, but supply only a fraction of the country's requirements. The country is even more deficient in the fertilizer materials, phosphate and potash. This is especially serious to a country requiring fertilizers for a large part of the food production. Enough salt is obtained from sea water to meet half the nation's needs, but the process is too expensive for the chemical industry there.

In addition to the foregoing metals and minerals, Japan has a scattering of nearly all other common, and many rare, minerals. Generally, however, production has not been economic for any appreciable quantities.

Poor as Japan is in most minerals, the country built many processing plants to treat foreign ores, thus enabling it to meet or exceed consumption requirements in steel, ferroalloys, sulphuric acid, magnesium, aluminum, superphosphate, and copper.

U. S. more fortunate

In all respects the Japanese mineral industry is much smaller than the American. Production capacity over 1000 tons daily is large for metal mines, and 500,000 tons per year is large for coal mines. Coal seams as thin as 18 in. are being mined, and a 16-ft seam is exceptional; the average is 4 to 6 ft. Practically no coal is being mined by open pit. Many of the large mines are over 1000 ft deep vertically, and working places may be several miles from the pit mouth.

Metal mines fit nearly the same description, with a few notable exceptions. The outstanding lead-zinc mine has ore shoots that measure scores of feet in diameter and hundreds of feet vertically. Two sulphur-pyrite mines have massive deposits totaling scores of millions of tons. In one copper mine is a single continuous ore body which has already produced 21,000,000 tons of ore containing over a billion and a half pounds of copper and ten times that much of pyrite.

Mining methods are uniformly small scale. The common denominator is what a team of two or three men can muck, drill, and blast in one shift. However, at the peak of war production, in 1943 and 1944, these methods brought several of the metal mines to a crude-ore production rate of several thousand tons a day, and the Miike coal mines exceeded 4,000,000 metric tons from four connecting pits in 1944.

Milling methods at metal mines include a mixture of hand picking with flotation designs of the late 1930's, plus jigs and tables where the equipment has survived. Heavy-media experiments are now being made on the basis of American successes. Hand picking of ore has flourished because the exclusive use of blast furnaces makes it necessary to furnish coarse sizes to the smelters.

Blast furnaces are suited to the numerous small treatment plants scattered from one end of Japan to the other. Electric refineries are generally located adjacent to the smelters, but their operating efficiency is comparatively low. None of these plants exceeds 20,000 tons annually.

By the end of 1948, foreigners were still limited, to the buying and selling of goods, with SCAP as the intermediary, controlling items, currency, and quantities. SCAP are the initials for Supreme Commander for the Allied Powers which is both MacArthur's title and the name of the Allied organization which deals, exclusively, with Japanese civil affairs. It has not permitted mineral investments by foreigners and presumably will not do so until a peace treaty, or a substitute, is concluded. Japanese law prevents foreigners from holding mineral rights except through Japanese companies.

The Japanese mining companies are desperately in need of American mining equipment and supplies but they have had no opportunity to acquire dollar credits. Since the end of the war total Japanese imports have been about double the value of exports. Japan is in need of practically everything she produces and much more. Only by endangering her already low standard of living could she, by herself, export consumer goods to acquire foreign food and industrial equipment.

The Japanese struggle for economic survival would be barbaric without American aid, but a question may be raised as to whether our aid will bring any financial benefit to the United States. Japan normally turns to other oriental countries for most of her imports and exports, and so great is the energy and ambition of the Japanese people, they will probably dominate oriental commerce eventually, with or without our aid.

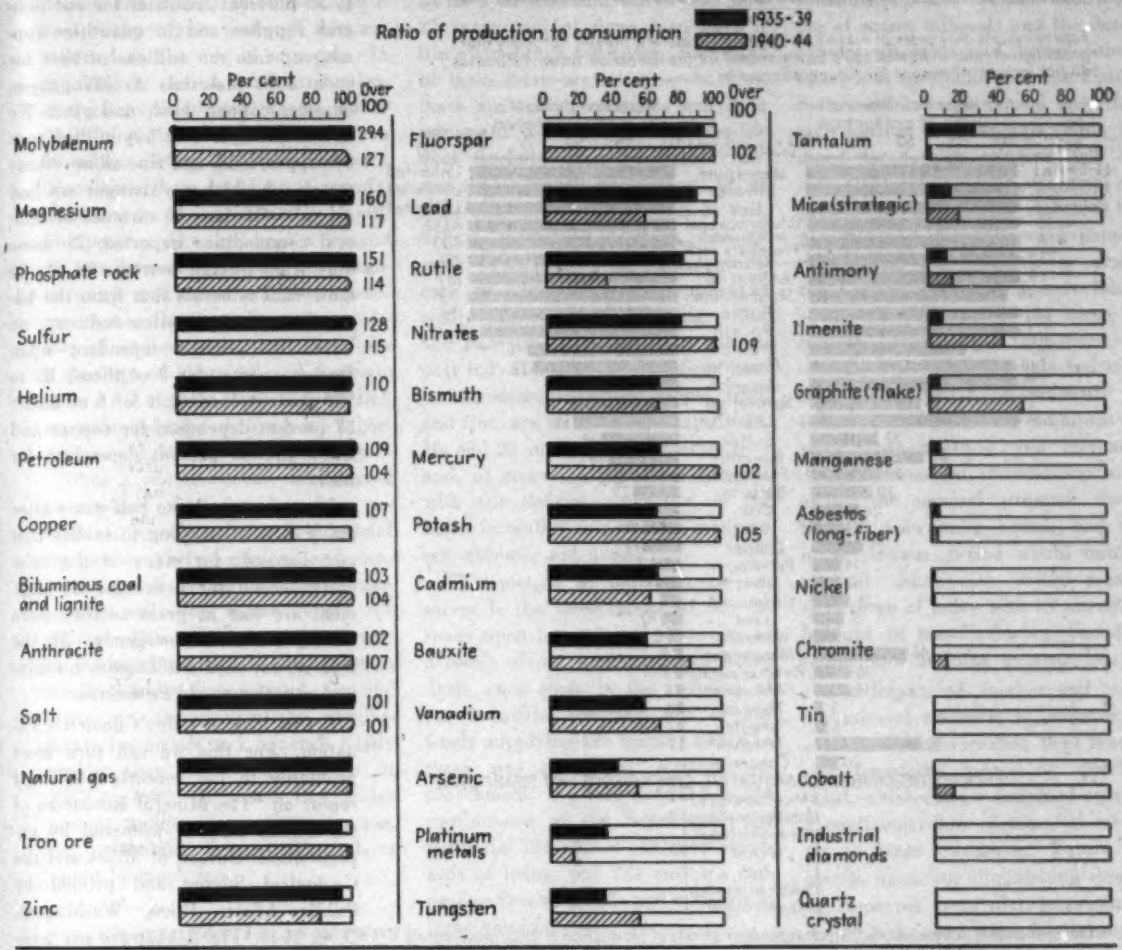

Fig. 1. The stress of war should have caused us to achieve greater self-sufficiency in more minerals than is evident in this table, but failure to do so is attributed to lack of reserves, depletion of reserves, and shortages of manpower and equipment.

America's Stake in World Mineral Resources

By ALAN M. BATEMAN • ECONOMIC GEOLOGIST, CONSULTANT; MEMBER, AIME

Before World War II we proudly considered that we were the nation of all the world most richly endowed in mineral resources. We knew it was no accident that those countries abundantly supplied with mineral resources became the great manufacturing nations, and the politically and militarily strong ones; and that our own great industrial cities sprang up where coal and iron met. We all realized, especially we of the mining profession, that the energy of fuels and the solidity of metals spelled industrial growth and in turn industrial might and that other nations came to regard mineral self-sufficiency as one of the chief goals of economic nationalism. It is now startling to realize that the insatiable demand for minerals to sustain our own industrialized economic life has caused us to dig and consume more minerals within the period embracing the two world wars than in all our previous history. The war made still further inroads. Our former bountiful sup-

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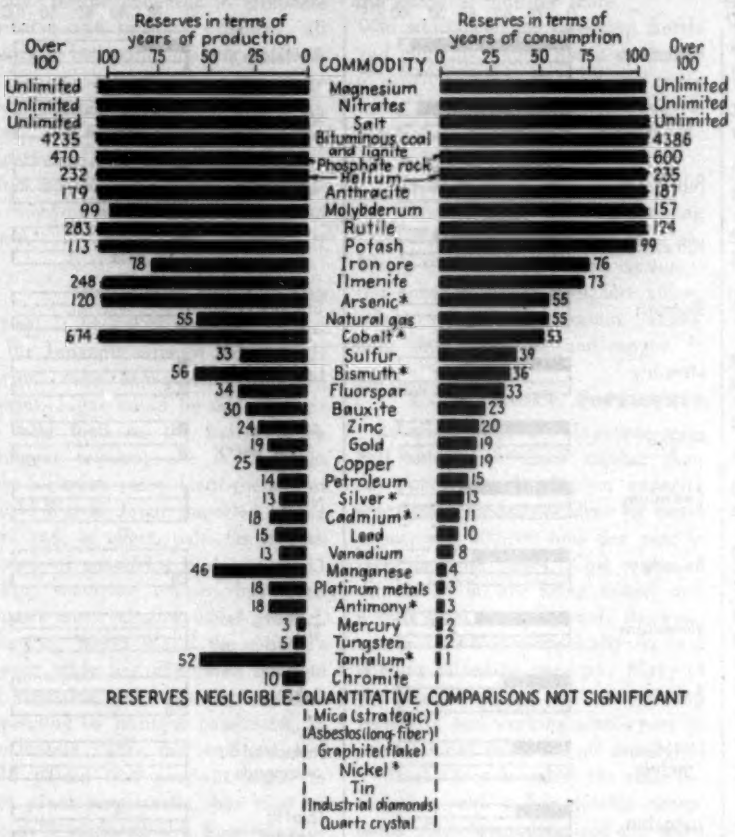
ESTIMATED "COMMERCIAL" RESERVES AS OF 1944, IN KNOWN DEPOSITS, COMPARED WITH 1935-44 ANNUAL RATES OF PRODUCTION AND CONSUMPTION

Figures indicate only order of magnitude of estimated reserves. They do not imply that production at rates indicated could be maintained for the full period shown. Estimates do not include allowance for future discoveries



* Obtained chiefly as byproducts. Output dependent on rate of production of associated metals

Fig. 2. Significant in this table of estimated reserves is the fact that our staples, copper, lead, and zinc, are way down the list in the ten to twenty-year group.

plies show serious depletion, and there still persists a smug complacency that all we need to do is to go out and dig more. The more we manufacture, the greater are our inroads upon the very basis of our manufacturing; the more goods we ship abroad, the more we deplete our resources, and in metals that mostly do not return to us in scrap.

We had always been keenly conscious, of course, of the dozen metals that we used to call our strategic minerals. But it took the shock of war to bring home to us that our dozen strategic minerals had grown to five dozen, that former adequate supplies began to look meagre, and that sources of large supply are becoming fewer and fewer.

war minerals imported

Let us consider briefly our mineral situation during the emergency of war. Our main problem was to obtain rapidly and in quantity those minerals essential for war production. Our own production was speeded to the maximum output permitted by scarce equipment and labor. It shortly became evident, however, that our assumed domestic abundance was woefully inadequate to meet the heavy war demands. It wasn't a case of merely trying to import what metals and minerals were available, because the quantities required exceeded the entire available world supply. Ores from new sources had to be sought, examined, mined, and transported to our shores to feed the hungry maw of our war machine. We had to turn to 53 different countries for our mineral supplies and in quantities running up into the millions of tons for such bulk materials as manganese, chrome, copper, lead, and zinc. We had to bring in over 5½ million tons of copper, lead, and zinc alone—three metals of which we thought we had enough. Of some 60 varieties of mineral commodities imported, 27 came only from foreign sources. Of the 20 most vital minerals that form the basis of war and peacetime industry, we were 100 percent dependent upon foreign sources for 8 of them; 85 to 100 percent dependent for 6 of them; 37 percent dependent for copper and zinc; and 44 percent dependent for lead.

Now, three and one half years after the war, it is startling to realize that our demands for many of the minerals needed for peacetime development are just as great as they were during the war emergency. If the bells of war should toll again, our mineral situation would be serious.

Let us look at today's domestic situation. For this we can turn most profitably to the recently published report on "The Mineral Resources of the United States," prepared by experts of the Bureau of Mines and the Geological Survey and printed by Public Affairs Press, Washington, D. C. 1948. Fig. 1 portrays our position in 39 principal minerals in terms of two 5-year periods; i.e. 1935 to 1939 and 1940 to 1944, one before and one during the war. Before the war our *production* equalled or exceeded our *consumption* in eleven out of the 39 minerals, including salt, helium, magnesium, coal, oil, gas, sulphur, phosphates, and copper. Several of these you will note are not vital minerals. For another twelve minerals of the 39, our production yielded only from 50 to 100 percent of our needs; for six, it ranged from 10 to 50 percent; and for the last ten of the 39 minerals, it ranged only from 0 to 10 percent. This prewar consumption vs. production record is *factual*, and gives a picture of the availability of domestic resources under the economic conditions existing between 1935 and 1939. It is not too happy a picture. Moreover, we must

consider that in the decade, or the decade and a half, since then, pertinent changes have occurred that are reflected in the use of minerals. In the 1935-39 period, steel production, as a gauge of industry, was as low as 28 million tons and no higher than 50 million. Today it is 93 million tons. Since then there has been a population increase of approximately 15 million people; there has been a demand for new homes; there have been higher wages and more available spending money than in all previous history of any country; there has been a shortage of industrial and domestic labor. All of these items have spelled an unprecedented demand for labor-saving and former luxury articles.

Once a people become accustomed to luxuries, they consider them necessities; once mechanized industrial equipment proves efficient and economic it will not be discarded—competition will adopt it and its use will expand. This is only a part sample of the economic trend, but even this small sample demonstrates for the future an increase in the requirements for metals and minerals vastly greater than those requirements of 1935 to 1939. It means that under present and prospective consumption, the percentage figures given above would be much less.

shortages in reserves

Those enhanced mineral demands of the future immediately bring up the question of the ability of our domestic reserves to meet the indicated future demands. Few of us have the requisite information to survey the resources of the entire mineral field. Therefore, let us turn again to the "The Mineral Resources of the United States," which represents the combined opinions of a large group of mineral appraisers working over the problems for a long time. This part of the report departs from the factual to the conjectural and we must appraise it in that light. Fig. 2 gives estimates of the life of our reserves based upon the ten-year period 1935 to 1944 rate of consumption of 41 principal metals and minerals. For fifteen of these 41 minerals our estimated reserves would last a half century or more; three would last us from 33 to 39 years; the remaining 23 have an indicated life of less than 25 years, and of these nine have a life of less than ten years. For eight of them there are no reserves. Now these are telling estimates and it is important to note that the long-life ones include many common substances of minor importance, or of wide sources of supply, such as salt, helium, magnesium, potash, and arsenic. Fortunately the figures indicate we have abundant supplies of coal, iron, and molybdenum. But, and here we must take note, the report indicates that our backbone nonferrous minerals such as copper, lead, and zinc, are all too short, namely 19, 10, and 20 years of life respectively—and, of course, everyone is familiar with our deficiency position in the basic ferroalloy minerals of manganese, chrome, and nickel.

This picture of our domestic reserves is the consequence of our inroads upon our mineral resources as a result of our long-continued heavy drain upon them in the building of our industrial machine, and of our freely supplying the world. Added to these was the heavy wartime encroachment. We look forward to the continuance of the benefits of our industrial life and of our good standards of living, and this means a continuing flow of metals and minerals in large volume.

foreign sources needed

Wartime and subsequent peacetime developments have demonstrated all too clearly that three principal industrial metals, copper, lead and zinc, and perhaps also petroleum, have changed from the role of abundance to scarcity. Since 1942 we have been net importers of the three metals, and recently of petroleum. During the last year, foreign copper consumed in the United States has amounted to between 25 and 30 percent of United States primary production. It seems doubtful, in my opinion, that we shall ever return to self-sufficiency in those metals as well as in other metals and minerals. I think we have to face clearly the fact that we are approaching a crisis in our mineral situation. Despite extensive mineral exploration that must be intensified in this country, and aggressive research in ore beneficiation, and despite the wiser use of scarce minerals and the development of more and better substitutes, it is inevitable that the United States will have to depend upon foreign sources and minerals. This demand for foreign minerals will increase not only because of normal depletion of our mineral reserves, but also because of our growing population which will continue to desire rapid transportation and more labor-saving devices both in the home, in industry, and on the farm—and all of these are made of metals and minerals. This demand is presently intensified by industrial mobilization, stock-piling urgency, and increased defense armament. Should war arise again, the mineral situation would become even more acute; and another postwar period would entrain mineral deficiencies vastly greater than those of today with its attendant holdups in manufacturing, transportation, and building construction.

The impact of another war upon our mineral resources is, however, of even lesser consideration than that of our long-term, peacetime development, which can be sustained only by a continuous flow of essential minerals in large quantities. Future demands upon our diminishing domestic resources mean that, increasingly, the United States will have to become more internationally minded with respect to minerals and to become more cognizant of foreign mineral potentialities. Steps should be taken by the government to assemble foreign mineral information by properly qualified technicians and to keep it up to date for the use of private industry and government planning.

politics abroad threaten supplies

Our need for future foreign minerals indicates the desirability of reviewing international affairs with respect to how major political developments may affect sources of mineral supplies. Already, since the war, we have witnessed the dropping of the iron curtain in front of mineral resources that formerly fed the industry of central western Europe. Now

the extensive zinc-lead deposits of Poland, Silesia, and Yugoslavia; the nickel of Petsamo, Finland; the copper and chrome of Yugoslavia; the manganese of Hungary; the bauxite of Hungary and Yugoslavia; the antimony of Yugoslavia; and the uranium of Czechoslovakia and Eastern Germany, all flow in behind the iron curtain and do not reappear. It is true these supplies formerly moved mostly to western Europe, but their removal from western European utilization creates demands upon other sources in competition with those of the United States. Russia used to supply about one half of the world's needs for manganese and was our chief source of supply, along with chrome. Now, within a month, the flow of these basic commodities from Russia to us has practically ceased. Unless this flow can be re-established, a serious manganese situation will change into a precarious one.

India was our next principal source of manganese supply and during the war was our chief source, but political developments there have reduced the flow of Indian manganese to a mere trickle. India also has threatened what is essentially a prohibition of exports of titanium ore and kyanite. American consumers fortunately have been able to obtain supplies of kyanite from a discovery in Kenya, and Quebec will shortly be able to supply the world with titanium products for pigments. It will be noted, however, that political actions have intervened in commercial transactions and their re-establishment will involve bilateral political negotiations.

Political developments in the Netherland East Indies, and our attitude toward them, could constitute a serious threat to the continued flow of vital raw materials. Similarly, political development both in China and Madagascar have practically eliminated the flow to us of tungsten and antimony from China and interfered with that of graphite and mica from Madagascar.

It is still too early to foresee what may eventuate from United States political policy concerning Palestine with respect to Middle East oil. The proven reserves of oil there are already nearly 50 percent greater than those of the United States and its potential reserves will probably exceed 200 billion barrels. Its wells average about 5000 barrels of oil per day against 13 barrels a day for ours. The day will surely come when we shall have to lean heavily on this Middle East oil. The interests of Great Britain and the United States are closely interwoven in Middle East oil, in which their ownership is greater than ours. These few examples serve to demonstrate the manner in which major political developments may effect international trade in minerals.

mineral foreign policy needed

Thus far I have tried to convey the need for frank realization that mineral imports are imperative to our future security and industrial development, and that such imports may lie beyond the scope of normal commercial transactions. This points to the necessity of the assistance of Government to help maintain an adequate flow of essential minerals. Procurement negotiations directly between private consumer and private producer are always desirable but where political developments intervene that restrict international trade, then this may no longer be possible and recourse to negotiation between governments becomes necessary. It means that the mineral consuming industry in the future will have to lean more heavily on Government, and Government will have to learn to support industry—the two will have to learn to become better team mates. This points to the necessity of establishing a national mineral policy as a part of our foreign policy to help guide and implement our future mineral welfare, and to help avoid ill-advised hand-to-mouth actions. Indeed, in dealing with those countries whose economy is largely dependent upon mining, a mineral policy might well determine our foreign policy. Action in this field is essential since our prosperity and security rest upon availability of mineral supplies.

Our own past record has not indicated a consistent appreciation of our mineral problems. Our mineral tariffs have fluctuated with changing administrations or under pressure of local area groups, too often with disregard of the consumer or the public; some tariffs exist that tend to keep out minerals that should be encouraged to flow in; and we have been lax in supporting American investment in foreign mineral production. Future diplomacy directed to dealing with the minerals upon which our prosperity and security are based is of the utmost importance to assure our share of world resources and that our mineral supplies do not fail.

The problem of foreign mineral resources sharpens as we consider some of the political developments in the source countries. In the case of manganese we probably cannot rely on Russian ores and shall have to look to India, the Gold Coast, South Africa, and Brazil, and political developments in two of these countries are presently deterrants to export and development. In the case of metallurgical chrome, world sources of large supply have narrowed considerably. It is unthinkable that our principal supply be left to the whim of a presently unfriendly Russia. New Caledonia cannot fill our needs; most of the Brazilian supply is gone; that of India is negligible, and Yugoslavia sources are closed to us. This leaves Turkey, Southern Rhodesia, and a minor amount from the Philippines, as our principal sources of future supply. Turkish chrome involves dealing with a State bank whose policies in part are political and political considerations are involved. Large Rhodesian shipments cannot take place until changes take place in Portuguese owned ports—again political considerations.

In the case of copper we are facing an entirely new problem in establishing new and dependable sources of supplies for the future. About two thirds of the world's foreign output comes from four countries, namely Chile, Northern Rhodesia, the Congo, and Canada. Of these, the output of the Congo goes to Belgium, and by long-term arrangement, to Great Britain. That leaves Chile as the only large source of American supply for the future. Chile's copper reserves in years of life vastly exceed those of the United States; but copper mining in Chile is not devoid of political com-

plications. It means that our foreign policy with respect to Chile must be so arranged that the two countries always remain on such friendly terms that Chilean copper will continue to flow to the United States; and under conditions that inure to the benefit of both countries.

In the case of lead and zinc we must look, in addition to Canada, to Mexico, Peru, Argentina, and Bolivia. Formerly, the United States' tariffs diverted these metals to Europe and shut out the flow to this country. Henceforth, we must seek it, but to do so involves delicate bilateral political adjustments of major importance. For adequate tin supplies we must have good understanding with the Netherlands, Malayan, Indonesian, and British Governments. We will have difficulty in obtaining adequate supplies of antimony and tungsten without an understanding with China; of bauxite without agreement with Holland, Surinam, and British Guiana; of mica unless we are on trading terms with India and Brazil; and similarly of many other minerals and countries. These various commodities are not susceptible to unrestricted commercial trading until certain political considerations are arranged between the governments involved.

trade barriers surmountable

The political considerations that call for diplomatic negotiations are many and varied. Among the most troublesome are the many trade barriers that have arisen, oftentimes injudiciously, and in part economic or political, in part retaliation. These take the form of tariffs, excise taxes, high export taxes, production taxes, high port or barging taxes, unfair artificial rates of exchange, allocations of foreign exchange, restrictions on outflow of capital and dividends, excessive transportation charges on nationalized railroads, and others. Some of the above trade barriers are levelled, in fact, if not in name, against American companies producing minerals in foreign areas. Among the more vicious of these is pegged exchange whereby dollars received from mineral sales brought back for purposes of paying local operations are required to be exchanged into local currency at rates much below the going commercial exchange. Another type of unfortunate exchange control is where local governments may determine how much dollar exchange may be permitted for the purchase of equipment, repairs, remodelling or improvements—a care of nontechnical, political personnel passing upon highly technical and managerial decisions that might be the making or undoing of a minerals operation. Still other diplomatic negotiations are called for in cases of restrictive laws, discriminatory legislation, some nationalized mineral industries, decrees relating to sales based upon sellers' weights and assays, permissible supervisory staff, sanctity of contracts, and numerous others. Above all is the necessity for teamwork between American producer or purchaser and the Government, in support of meritorious foreign operations. These various hurdles sound formidable and discouraging to American mineral consumers who desire to procure or produce minerals abroad. However, with patience, learning the "know-how," a sympathetic attitude to the other man's viewpoint, and strong diplomatic assistance, the hurdles are not insurmountable. Once good trade relations become established and integrity assured it tends to engender good neighbor and friendly political relations.

Today the United States is being called upon as never before to take a broadening part in world affairs. It is timely, therefore, to consider that as this nation has freely sold its minerals to all who cared to buy, and thereby helped deplete its resources, so it should be permitted to purchase freely where it may. At a time when this country is shipping abroad vast quantities of its diminishing materials in the form of manufactured goods to aid the world, it is justifiable and fitting that a vigorous and alert *quid pro quo* approach be established with the frank objective of obtaining metals and minerals for our present and future needs, under conditions that will be mutually beneficial to all concerned. We could negotiate for the elimination of foreign trade barriers, and in turn give up some of ours; we could obtain concessions in foreign mineral procurement and development, and in turn agree, during periods of economic depression in those countries whose economy is largely dependent upon raw materials, to purchase for stock pile or industry certain minimum quantities of minerals of which we are deficient, and thus provide a cushion beneath their ugly fear of no available markets for their minerals. We could thereby obtain needed minerals; we could remove the gaunt spectre of unemployment with its attendant low standards of living in those lands that subsist largely on mineral production. These, and more too, are examples of what might be done to assure American access to foreign resources.

What I have said clearly indicates that America's stake in the mineral resources of the world is great, and points to the pressing need for a sound mineral policy incorporated in our policy, with the ever pressing objective of assuring at all times an adequate supply of minerals to meet the industrial and security needs of the nation. One cannot overlook the fact that the Soviet Union has abundant and almost untapped supplies of the backbone minerals, fuels, and iron; the complementary ferroalloy minerals; because of the iron curtain, the bulky nonferrous metals; and those which she lacks can be flown in. When her great population learns the "know how" and becomes industrially minded, as they are rapidly becoming, and her plants and industry expand, the mineral resources within her territory, supplemented by those within her sphere of influence, bode to make her the industrial giant of the future. There is thus in the making a great military power backed by potential industrial might, and fed by an abundant supply of mineral resources combined with the confidence that comes with a knowledge of ownership of those resources. Here then is a further challenge to establish an alert and sound mineral policy ever on the *qui vive* to open avenues to obtain those waning mineral substances that are the foundation of security and future industrial prosperity.

Continuing a new department which is intended to disseminate the latest operating practices in open-pit mining, we hope that our readers will continue to contribute information on their operations or discussion of the subjects presented.

Forum on Open Pit Mining

Tungsten Carbide Bits for Blockholing at Ajo

By ALFRED T. BARR • MEMBER, AIME

In certain areas of the New Cornelia pit, considerable secondary blasting is necessary to reduce oversized boulders, formed from primary blasting, to pieces which will pass the 4½-cu yd dippers on the shovels. Some of the boulders are 'dobied, but when time permits they are blockholed and blasted. In most instances one hole drilled to a depth of 2 to 3 ft and blasted with 1/3 to ½ of a stick of powder will break a boulder satisfactorily. Blockholing is normally done by using a jackhammer of the 55-lb class, 1-in. round drill steel, and detachable steel bits, 2-in. gauge when new. A bit change is usually made after the completion of each hole.

The use of light drilling equipment in blockholing is desirable, both from the standpoint of safety and ease of doing the work, and when it was seen there was a possibility of using a lighter jackhammer through the use of tungsten-carbide bits and at the same time get at least the same drilling efficiency as with the standard equipment, it was decided to test tungsten-carbide bits. The claims for long life of the bits and footage drilled before resharpening gave hopes of eliminating much of the delay time in changing bits which is unavoidable with the use of steel bits, and thus gain in actual drilling time.

test no. 1

The purpose of this test was to determine the footage which could be drilled with a tungsten-carbide insert bit before resharpening was required, the total footage which could be drilled before the bit was ready to be discarded, the drilling rate, and the time required for resharpening the bit.

The drilling equipment consisted of a jackhammer of the 30-lb class, ⅞-in. hexagon drill steel, and a tungsten-carbide insert bit, 1½-in. gauge, 4-point cross design. During the test, 170 holes averaging 2 ft in depth were drilled in hard rhyolite boulders which had been set out by a shovel operating along one of the banks of the pit. Forty boulders were blockholed per drill shift, which was appreciably more than the average with standard equipment under normal working conditions. Table 1 shows the results of the test.

TABLE 1. RESULTS OF FIRST TEST SHOW PERFORMANCE OF TUNGSTEN-CARBIDE BIT.

Bit usage	Gauge (inches)	Footage drilled	Drilling Rate (in./min.)	Resharpening Time (min.)
1st	1.5	75.91	9.8	
2nd	1.45	70.00	9.7	27
3rd	1.40	55.83	9.1	26
4th	1.39	27.83	9.7	10
5th	1.375	31.33	8.2	22
6th	1.312	71.32	9.9	17
All	1.27*	332.22	9.2	

*Gauge at end of test; bit considered ready for discard.

test no. 2

The purpose of this test was to determine the relative drilling rates of a tungsten-carbide insert and regular steel bits with the same jackhammer and otherwise under the same drilling conditions.

TABLE 2. COMPARISON OF BITS REVEALED BY SECOND TEST RESULTS.

Type of bit	Number of holes drilled	Inches drilled	Drilling Rate (inches/min.)	Number of bits drilled
Tungsten-carbide	10	259	10.33	None*
Steel	10	237	7.35	10**

*Showed little wear.
**All bits dull.

The drilling equipment consisted of a 30-lb jackhammer, ⅞-in. hexagon steel, a tungsten-carbide insert bit with a gauge of 1.413 in. and steel detachable bits with approximately 1 9/16 in. gauge. During the test 10 holes were drilled with each type of bit in hard monzonite boulders. Table 2 shows the results of this test.

The results of this test proved that the tungsten-carbide bits will give much better performance with the light drilling equipment than the regular steel bits.

Paper presented at the annual meeting of the Arizona Section on Dec. 7, 1948.

test no. 3

The purpose of this test was to determine the relative efficiencies of drill crews working under normal conditions for a considerable period of time with two types of equipment, one consisting of a 30-lb jackhammer, ⅞-in. hexagon steel, and tungsten-carbide insert bits; and the other consisting of a 55-lb jackhammer, 1-in. round steel and regular steel bits. It was also the purpose to develop during the test further information on the characteristics of the tungsten-carbide bits. In the course of the test, lasting over a period of about 4 months, 15 tungsten-carbide bits were run to destruction and data on one make of bit was pretty thoroughly developed. Table 3 shows a summary of the results of the test as well as comparative cost data based on these results.

TABLE 3. SUMMARY OF RESULTS OF TEST NO. 3 TO DETERMINE RELATIVE EFFICIENCIES.

	Drilling Equipment	
	No. 1 (Tungsten Carbide Insert Bits)*	No. 2 (Regular Steel Detachable Bits)
Number of drill shifts	62.8	41.9
Number of holes drilled	2261	1098
Total footage drilled	5919	3187
Holes per drill shift	36	26
Footage per drill shift	94.3	76.1
New bits used	15	112
Number of bit usages	72	818
Number of bit sharpenings	57	706
Average footage per bit	395	28.5
Average footage per bit usage	82.2	3.9
Total Cost—		
Labor (drill crew only)	$1,245.95	$831.30
Tungsten-carbide insert bits @ $12 each	180.00	
Steel detachable bits @ $0.35 each	—	39.20
Sharpening bits	28.50	53.66
Totals	$1,454.45	$924.16
Cost per drill shift	$ 23.16	$ 22.06
Cost per hole drilled	.64	.84
Cost per foot drilled	.246	.290

*For record of individual bits, see Appendix No. 1

APPENDIX NO. 1
TUNGSTEN CARBIDE INSERT BITS NO. 1-15 INCLUSIVE

Used in Test No. 3

Bit No.	Number of usages	Total footage drilled	Ave. footage per usage	Number of Sharpenings	Average resharpenings time (minutes)
1	5	304.6	60.9	4	19.5
2	5	350.2	70.0	4	15.2
3	6	448.7	74.8	5	16.2
4	6	289.3	48.2	5	15.2
5	5	349.9	70.0	4	19.7
6	5	300.3	60.1	4	15.0
7	4	396.1	99.0	3	15.7
8	5	276.6	55.3	4	14.3
9	4	387.9	99.5	3	18.3
10	4	507.6	126.9	3	19.3
11	5	447.3	89.5	4	21.0
12	5	666.4	133.3	4	16.3
13	4	450.7	112.7	3	16.3
14	5	372.5	74.5	4	15.5
15	4	371.0	92.8	3	19.7
Totals	72	5,919.1	—	57	—
Averages	4.8	394.6	82.2	—	17.1

Trucks and Shovels at Inspiration

Omaha Public Library
Reference Dept.

By J. R. WATTS • MINE SUPERINTENDENT; MEMBER, AIME

In the early part of 1947, the Inspiration Consolidated Copper Co. decided to change from underground to open-pit mining in portions of the existing ore body. Development work was started the first part of March 1947 by an outside contractor and carried on until enough of our own equipment was available. Much thought and study was given to the purchase of equipment for the job and especially to suitable types of shovels and haulage trucks.

Dart haulage trucks and P&H 1400 shovels were decided upon and have proved satisfactory. The interesting development in the P&H shovel is the use of the magnetorque unit. This eliminates many operating mechanical parts, thereby reducing wear and upkeep. The hoist motor is an a-c 25-amp 2300-v induction motor. This motor drives the hoist machinery through the magnetorque unit. The latter is a device for transmitting torque by means of electromagnetic forces. The magnetorque unit consists of two simple members, an outer member with field coil and inner member without field coil. The inner member revolves within the outer member. The outer member is mounted on the shaft which runs inside the pinion quill and is driven at constant speed by the hoist motor. When electric current is supplied to the windings on the outer member, a magnetic attraction is set up between the inner and outer members, causing the inner member to rotate and hoist the dipper. The torque transmitted to the inner member depends on the amount of current applied to the winding. However, the torque also increases rapidly with a decrease in dipper speed, reaching a maximum when the dipper is stalled; thus producing the required characteristics of high torque at low speed and low torque at high speed. The magnetorque unit has what might be termed a "flywheel" effect. By releasing the hoist brake, when no current flows to the coil of the outer member, the dipper lowers by gravity. The hoist motor never reverses. We find that in the use of this unit, power is smoothly applied and the response, particularly during plugging and after the dipper is lowered, is much more rapid.

For hauling ore and waste, a fleet of nine Dart trucks with 14-yd Heil bodies powered by Hercules DFXH diesel engines is used. The engine, which is not supercharged, develops 210 hp after all allowances.

XUM

Alloy-Steel Bits Tested at Morenci

By L. ORMSBY • MINE SUPERINTENDENT; MEMBER, AIME

An investigation of alloy steels for churn-drill bits was conducted at the Morenci open pit to secure actual comparative drill costs using standard carbon steel churn-drill bits in direct comparison with various alloy bits. The alloy steels used were selected after consultation with various West Coast steel companies with primary consideration being given to types of steel which could be water quenched and heat treated without too much change in the standard mine bit shop operation.

The drilling tests were conducted under the supervision of William Damon, bit shop foreman, at the Morenci open pit and covered the period from December 1947, to April 1948.

All of the bits used were made to the standard Phelps Dodge pattern for nine-inch blastholes and each steel was treated and sharpened according to the manufacturer's specifications. The regular carbon steel bit used in the Morenci open pit is a modified C 1055-1060 averaging 0.55 carbon and 0.79 manganese. For the test, eighteen numbered alloy bits were made up in groups of three incorporating steels as shown in Table 1.

Comparative field tests were made using an alloy bit and a carbon-steel bit on the same drill and within the same area. The average footage drilled for each type of alloy steel and its comparative carbon-steel bit per sharpening is as follows:

TABLE 2. RESULTS OF TESTS SHOWING COMPARATIVE FOOTAGES

Bits	*Type*	*Alloy bit footage*	*Standard bit footage*
100, 101, 102	6150	92.1 ft.	84.7 ft.
103, 104, 105	4340	84.5 ft.	88.9 ft.
106, 107, 108	4150	80.1 ft.	78.9 ft.
109, 110, 111	4340	78.8 ft.	80.8 ft.
112, 113, 114	Special	80.8 ft.	78.3 ft.
115, 116, 117	Special	61.3 ft.	63.4 ft.

As is apparent from the figures in Table 2, the footage achieved with the alloy bits was not superior. Comparing the cost of the alloy steel and the regular carbon bit, it is believed it would be necessary on a straight footage basis to drill about 40 percent more footage with the alloy bit in order to have the same cost per foot, other factors remaining the same.

Another factor which would influence the decision is the number of sharpenings possible on the alloy-steel bits before discard. To date, seven of the alloy-steel bits have been discarded with average sharpenings of 28. The average bit sharpenings for the total carbon-steel bits used in the Morenci pit are computed semiannually with a figure of 79.1 uses per bit before discard. One reason for the low use on the alloy-steel bits was the considerable breakage which necessitated cutting off and reforging. The apparent reason for the breakage in use and forging of the alloy steels could be accounted for by the depth of zone of hardness and resultant loss of ductility.

It is believed that most of the breakage in forging had occurred while the bit was in use, and was not due to heat treating or forging in the bit shop as the forging presented no special difficulties other than a slightly higher temperature required which would shorten furnace life. While the ideal heat treatment for alloy steels would be oil quenching, the Morenci bit shop procedure of water quenching was not changed.

There was no question about the quality of the steels used but it became increasingly apparent as the tests were conducted that we were attempting to solve a problem which hollow air-drill steel users had had until the introduction of the detachable bit. In other words, the cutting edge had to be such that it could be hardened sufficiently to do its work without premature dulling and yet the body of the bit had to be sufficiently tough to resist breakage induced by fatigue. The combination was apparently not achieved and the conclusion reached is that these alloy steels are not suited for churn-drill bits.

TABLE 1

Alloy Bits, in Groups of Three, for Comparison Test with Carbon Bits

Bit Number	100, 101, 102[1]	103, 104, 105[2]	106, 107, 108[3]	109, 110, 111[4]	112, 113, 114	112, 113, 114[5]
Alloy Steel	AISI-E-6150	AISI-E-4340	AISI-E-4150	AISI-E-4340	.....	A-4053
Grain Size	5-8	5-8	5-8	5-8	5-8	.....
Steel Analysis:						
Carbon	0.47-0.53	0.38-0.43	0.48-0.53	0.38-0.43	0.50	.....
Manganese	0.70-0.90	0.60-0.80	0.75-1.00	0.60-0.80	0.57	.....
Phosphorus	0.25	.025 (Max.)	0.04 (Max.)	.025 (Max.)	.....	.....
Sulphur	0.25	.025	0.04	0.025	.....	.....
Silicon	0.20-0.35	0.20-0.35	0.20-0.35	0.20-0.35	0.26	.....
Chrome	0.80-1.10	0.70-0.90	0.80-1.10	0.70-0.90	0.13	.....
Vanadium	0.15	.....	.....	.....	0.08	.....
Nickel	.....	1.65-2.00	.....	1.65-2.00	0.14	.....
Molybdenum	.....	0.20-0.30	0.15-0.25	0.20-0.30	0.44	.....

[1] Bits have annealed pin, collar and square.

[2] These bits were completely heat treated, pin and body, in accordance with the recommendations of the manufacturer.

[3] Bits have annealed pin, collar and square.

[4] Bits have annealed pin, collar and square. They have a similar steel with 103, 104, and 105, but because of the heavy cost involved in heat treating the whole bit, the pin, square and collar only were heat treated.

[5] Steel, special carbon, manganese, molybdenum.

Paper presented at the annual meeting of the Arizona Section on Dec. 7, 1948.

Metal Tariff Agitation Rides Again

By HAROLD A. KNIGHT • ASSISTANT EDITOR, JOURNAL OF METALS

The Miami Copper Co., Arizona, is asking Congress to reimpose the import duty of two cents per pound on copper which, by law, has been suspended until June 30, 1950. C. Donald Dallas, chairman of Revere Copper and Brass, champion of a duty-free regime as regards the red metal, has been answering E. H. Westlake, Miami president, now that Mr. Westlake's statement to stockholders has been salted away for posterity on wire recorders.

Even prior to this action and at the instigation of two prominent consumers of pig lead, the House of Representatives has, in the confines of committee, not yet reported out, as of June 16, a bill to suspend the duty on lead for another year from expiration of the present law June 30, 1949. But apparently the bill was started too late.

Thus the tariff issue becomes a Rip Van Winkle again after having slept for several years in the mountains of metals scarcity. During the wartime scarcity and the boom days that followed, most metal producers welcomed a considerable influx of foreign metal since it gave them a little surcease from constant telephone calls asking why that delivery of 300 tons of lead, 250 tons of zinc, and 1000 tons of copper had been delayed. These were the days when it was such an undisputed sellers' market that the sellers had even thrown away their certificates of ownership.

Another development that brings home the tariff situation, small in itself but perhaps indicating a trend, has been the announced closing of the Nevada-Massachusetts tungsten mine in Nevada, on June 25, the president giving three reasons, headed by "foreign competition under State Department encouragement of a low tariff"; also because of poor demand for tungsten and a consequent low price for the metal.

tariffs on "trinity" metals

The status of the tariff with regard to the three "trinity" metals, copper, lead, and zinc, is as follows. The basic duty on copper, theoretically, may be considered as 4 cents per pound, a figure imposed a few years before World War II. Actually this duty, if in effect, would be two cents because of a postwar conference at Geneva when the United States, in the interest of promoting international trade, agreed to cut it to that figure in return for concessions on American goods entering other countries, subject to the Geneva agreement. The import duty of four cents on copper was first suspended in April, 1947 until June 30, 1949. Recently it was extended by Congress for another year.

During this postwar era the duty on lead was also suspended because of the extreme scarcity which had developed, a scarcity which perhaps transcended that in the other two metals. This suspension of the duty of 1 1/16 cents per pound on pig lead and related lead items and 3/4 cents on ore, is due to expire June 30, 1949, but, as stated previously, a bill is now in the House committee to extend this suspension for another year.

Zinc is the only metal of the "trinity" on which the duty has not been suspended in recent years. The duty therefore continues at 7/8 cents per pound on slab zinc and 3/4 cents on concentrate, the two being consistent as regards metallic zinc content.

In lead there is a slight complication to the picture. Official lead duties, were they in effect — and should they be in the future, are to be raised a trifle, once the President proclaims an end of the national emergency, but in view of the present cold war with Russia there does not seem any likelihood of such raising to the decreed levels of 1.20 cents on ore and 1.70 cents on pig metal.

The revival of the tariff controversy has taken place, of course, because of the sudden sinking of prices, the sharpest revisions downward in so short a period in metal-market history, according to veteran observers. Thus, as this is written at the end of May, copper has dropped 5 7/8 cents from its top; lead has fallen 9.50 cents, and zinc has come down 6.50 cents.

The sharp decline in prices naturally reflects the sharp falling off in demand. Sales of lead have been running an average of 2000 tons weekly, whereas in late 1948 they were around 10,000 tons per week. Reflecting the sharp falling off in lead consumption, shipments of refined lead to domestic consumers in April were only 24,083 tons, a drop of 9250 tons for the month. April deliveries were the smallest since May, 1946. Shipments of refined lead during the first four months of 1949

were 44,000 tons less than for the corresponding period of 1948.

Since metal-market conditions in the United States are usually typical of conditions throughout the civilized world, it is assumed that metal producers in other countries are finding it difficult to sell metal and so may perhaps press their metal for sale into the United States with more persistence. This is what American metal producers are worried about and hence a natural reaction is for the imposition of tariffs to tend to keep this metal out, or at least confine it to relatively small tonnages.

copper men divided on duty

This considerable unanimity of opinion in favor of a duty exists among lead and zinc producers. In copper it is another story. Arizona copper producers, such as Phelps Dodge, with no foreign copper-producing properties, naturally favor a tariff; hence it was logical for the president of another Arizona producer, Miami, to fire the opening gun in the advocacy of a duty. The situation as regards Anaconda is entirely different in that it has very live subsidiary copper-producing companies, such as Chile Exploration Co. and Andes Copper Mining Co., abroad. Thus, though a copper duty would protect the copper produced at Butte, it would cause a hurdle for the copper turned out in South America.

Several stock arguments are bandied about, pro and con, concerning a metals duty. One argument in favor of free entry is that by importing foreign metals we save our own metals for a rainy day. But offsetting that argument is the fact that if we save our metals too much the American mines will fill up with water and mushrooms will grow in the adits.

On May 25, C. Donald Dallas shot forth a broadside against the Miami Copper Co. official who told stockholders he would ask Congress to reimpose a duty. Mr. Dallas admitted that there has been a flood of imports of foreign copper so far this year, or as 85,800 tons for the first quarter of 1949 compares with 59,800 tons for the corresponding period of 1948. However he stated that these high imports are not representative. They represent panic purchases made abroad late in 1948 when copper was extremely scarce and the long-drawn-out strike at the Kennecott properties in Utah showed no signs of being ended. It was at a time, too, when the government was purchasing heavily for stock-piling and when consumers were hoarding copper far and above their apparent needs. Again, purchasing of foreign copper in late 1948 was heavy because many believed that the duty on copper would be re-established, hence it was prudent to buy large quantities while duty was free. Mr. Dallas concludes his arguments as follows: "To sum up, there is nothing in the present unusual state of the industry to indicate that a tariff is needed. Certainly the evidence of the last two years has been that there is no need of tariff. Let us not seek the aid of Congress whenever a temporary condition results in a dearth of demand."

Going back a generation, the important duty of that time was the Fordney-McCumber tariff act, effective Sept. 22, 1922. Copper ingots entered the country free because we were distinctly a "have" nation among the common metals and we exported more copper than we imported and had no fear of being flooded by copper imports. It was apparently a slightly different story with the two other "trinity" metals. Thus lead carried a duty of 2⅛ cents per pound on pigs and 1½ cents on ore (against 1 1/16 cents on metal and ¾ cents on ore today—when the duty is in effect). Duties on zinc were then 1¾ cents per pound on slab zinc and 1½ cents on ore (as against ⅞ and ¾ cents today).

Metal duties in effect today are based on the Tariff Act of 1930, effective June 17, 1930, and the Revenue Bill, effective June 21, 1932. An important feature was that the President has discretionary powers to vary the existing tariffs as much as 50 percent, powers which he exercised in the case of metals. We recall the agitation on the part of the zinc industry when President Roosevelt cut duties on zinc to the full extent of the 50 percent in the middle 1930's. Zinc producers were indignant and probably rightly so because: (1) the cut in duty was in effect a cut in selling prices and many zinc producers were at the time skirting that narrow band which divides operating in the red from the same in the black. They predicted then that if a national emergency arose the zinc industry would be so run down as not to be able to supply sufficient zinc; (2) the President announced the cut in duty without apparently consulting anyone among the zinc producers and without allowing producers a say in the matter.

Old Guard Republicans have mostly died off. By evolution the features of the Republican elephant have tended to merge into the features of the Democratic donkey, until it takes keen insight and perhaps a good sense of smell to differentiate. It may be that this merger of the two animals was done perforce, or by the long triumphant rule of the Democrats and the predominance of the donkey. Biologists do say that the dominant form of animal life prevails.

We find that today's duties are lower than a generation ago, while selling prices of those metals are higher, so that the percent of duty, as based on sales price is a mere bagatelle. In 1922 the lead price for the year averaged 5.71 cents per pound, with the duty 2.125 cents per pound. Thus the duty was 37 percent of the sales price. As this is written, the price of lead is twelve cents and the duty is nil or zero percent of the lead price.

Or, take zinc. The average price of zinc in 1922 was 6.09 cents, with duty of 1.75 cents per pound, the duty thus representing about 29 percent of the selling price of zinc. Today, with zinc at nine cents and a duty of ⅞ cents per pound, the duty represents but 10 percent of the price.

Perhaps the conclusion to this exposition is that present duties are not much of anything to get excited over. Except for copper they certainly are trivial by comparison with those of a generation ago. Another thing to bear in mind, in considering the philosophy of tariffs, is that the United States is no longer the isolated nation that it was in 1922. The book, "One World," represents the thinking of the times. The lack of a tariff, or no more than a small duty, tends to promote international trade, and helps promote the concept of "one world."

ALL INSTITUTE SECTION

APPEARING IN:
• MINING ENGINEERING
• JOURNAL OF METALS
• JOURNAL OF PETROLEUM TECHNOLOGY

Text of Bylaw Amendment to Increase Dues Decided by Board at May 18 Meeting

Numerous matters of more than routine interest engaged the attention of the fourteen Directors who attended the Board meeting at Institute headquarters on May 18. Beginning with an informal luncheon session at 12:30 the meeting continued until 5:40. President Young presided, with the following Directors present: Messrs. Alford, Daveler, Elkins, Fletcher, Head, Kinzel, Kraft, Meyerhoff, Peirce, Phillips, Price, Schumacher, and Sullivan. Sixteen staff members and guests also attended.

The text of proposed amendments to the bylaws was discussed at some length with Edward Holloway, counsel, and the wording as given on another page of this issue was approved. The changes will be voted upon by the Board, according to the bylaws, at a meeting at least two months subsequent to May 18. They will provide for: (1) An increase of $5 in the dues of Members and Associate Members for the years 1950, 1951, and 1952; and for an increase in the dues of Junior Members of $2 for the same years; dues thereafter are subject to a referendum in 1952. (2) A change in the date when dues become payable from Oct. 1 to Jan. 1; members will receive the January, February, and March issues of the journals pending receipt of dues. (3) Elimination of the grade of Junior Foreign Affiliate at the end of 1949. (4) Limiting the term of Student Associateship to the end of the year of graduation, instead of the end of the following year as is the current provision. A special effort will be made to have graduating Student Associates apply immediately for a change of status to Junior Member, though action on their applications will not take effect until the end of the year.

Another matter that aroused considerable interest was the content of the All-Institute Section (Section 2) of the monthly journals. A difference of opinion developed as to whether all personals should be carried in this section, or whether they should be split up into items of particular interest to the three Branches and be published separately in Section 1 of the respective journals. Further discussion of this subject was postponed until the June meeting of the Board.

The advertising situation in the three journals was also reviewed. The mining journal is running somewhat ahead of M&M for the same months of 1948; the metals journal has contracts for $14,000 of the $15,000 income budgeted for the year; and the petroleum journal hopes for $20,000 this year, and at least double that two years hence.

With deep appreciation, especially so at this time, the Board received news of a bequest of £1000, free of English duty, which was left to the AIME in the will of one of its Life Members, William Henry Corbould, who died on March 16.

Reports were made of a preliminary study on the possibility of reducing expenses at AIME headquarters by a merging of certain activities of the four Founder Societies. It is believed that business machines might then be utilized which are not now practical for one society to use. The possibilities are to be investigated further.

A final financial report of the Annual Meeting in San Francisco was made, indicating that registration fees had netted $3708; tickets for various functions, $31,263; and contributions, $13,341. Of the last-named figure, 196 members donated $2381 and 75 manufacturers and companies gave $10,960. Total income was therefore $48,313. Expenses paid for by the San Francisco Section, including $947 returned to New York headquarters to pay a part of the cost of staff assistance at the meeting, amounted to $41,192, leaving a profit to the Section of $7120. This will be invested and used to help in defraying the expenses of future meetings, and to support Section activities. The AIME will have certain expenses not covered in the foregoing figures—chiefly traveling expenses of staff members from New York and Dallas.

Two tellers were appointed from each Branch to count the votes in the referendum for the increase in dues, as follows: Mining, F. X. Corbett and Robert B. Sterns; Metals, David Swan and Thomas A. Read; Petroleum, K. E. Hill and J. I. Laudermilk. The ballots will be counted on June 13, and a report made to the Board at its meeting on June 15. (Results of the balloting show that of the 11,618 ballots mailed, 6,923 valid ballots were returned, 5,403 voting yes, 1,520 voting no. For a tabulation of results see box on page 236.)

Certain changes were voted in the territory of Local Sections in eastern Pennsylvania. The Pennsylvania Anthracite Section's area will be confined to the counties and parts of counties in which there are anthracite mines; the Lehigh Valley Section will hereafter include Cornwall, Lebanon, Lehighton, and Palmerton; and the Philadelphia Section will include some of the area north of Philadelphia heretofore in Lehigh Valley Section territory.

Announcement was made of a survey being made for the U. S. Government to determine which members of various engineering societies have had experience in research and development, and have served in foreign countries. Members of the AIME will shortly receive a questionnaire for this purpose, and its prompt return, filled out as requested, will be appreciated. The work is being done on a contract basis by the ASME, with the co-operation of Engineers' Joint Council.

Ray P. Walters, AIME delegate to the recent World Engineering Congress in Cairo, submitted a detailed report of the meeting to the Board. He felt that technically the Congress was largely a failure. Strong efforts were made by Soviet countries to make political capital out of the meeting, but without much success.

A new Student Chapter, AIME, was recognized at the Institute of Technology, St. Louis University, with Albert J. Frank as Faculty Sponsor. Endorsement was again voted for the Welding Research Council, and its application for $1000 from the Engineering Foundation for its work in 1949. Fred M. Nelson was appointed to the Lucas Medal Committee for a four-year term, and Curtis L. Wilson was reappointed as AIME representative on Engineers' Council for Professional Development for three years. The ECPD annual report was announced as now available. Announcement was made of the United Nations Scientific Conference on the Conservation and Utilization of Resources, to be held at Lake Success, N. Y., Aug. 17 to Sept. 6. The Committee on International Relations of Engineers' Joint Council (of which the AIME is a member) will co-operate.

Immediately before adjournment, a memorial resolution for Sydney Hobart Ball, who died on April 8, was read. It was prepared by Donald M. Liddell.

Proposed Amendments to AIME Bylaws

By direction of the Board of Directors at its meeting on May 18, 1949, the following proposed amendments to the Bylaws of the Institute are published, to be voted on at the July 27, 1949, meeting of the Board, to be held in New York City.

(Add words italicized; delete words in parentheses).

To effect a temporary increase in dues:

Article II, Section 2:

Change second sentence to read as follows: "Dues of Junior Members *shall be* $10 per annum for the first six years of membership as a Junior Member, and thereafter $15; *except that the foregoing dues of Members and Associate Members shall be increased by $5, and of Junior Members by $2, for each of the years 1950, 1951, and 1952 only, unless, as the result of a referendum in 1952, the dues shall be otherwise determined.*"

To effect a change in the date when dues become payable:

Article II, Section 2:

Change fourth and fifth sentences to read as follows: "All dues (for the succeeding calendar year) shall be payable in advance on the first day of (October) *each calendar year*, except as provided in this section, and notice to this effect shall be published in the (September) *December* issues of the monthly journals of the Institute each year. A bill shall be mailed to each member liable for dues (on or before) *prior to* the first day of (October) *January* in each year, stating the amount of the annual dues, date when payable, and the penalty and conditions incident to default in payment."

Article III, Section 2:

In the first sentence, change the word "four" to "three."

To eliminate the class of Junior Foreign Affiliate at the end of 1949:

Article I, Section 1:

Revise first sentence as follows:

"The membership of the Institute shall comprise (seven) *six* classes, namely: 1. Members; 2. Honorary Members; 3. Senior Members; 4. Associate Members; 5. Junior Members; *and* 6. Rocky Mountain Members. (7. Junior Foreign Affiliates.)"

Article I, Section 8:

Delete entire section and renumber succeeding sections.

Article I, Section 10:

Revise first fifteen words as follows:

"Every candidate for election as a Member, Junior Member, *or* Associate Member (or Junior Foreign Affiliate) . . ."

Article I, Section 11:

Revise first sixteen words of second sentence as follows:

"Every person so elected shall become a Member, Junior Member, *or* Associate Member (or Junior Foreign Affiliate) . . ."

Article I, Section 12:

Revise first fourteen words as follows:

"If any person elected a Member, Junior Member, *or* Associate Member (or Junior Foreign Affiliate) . . ."

Article II, Section 1:

Revise first fifteen words as follows:

"Each newly elected Member or Associate Member, and each Junior Member (or Junior Foreign Affiliate) . . ."

Revise last sentence as follows:

"There shall be no initiation fee for Honorary Members *or* Junior Members (or Junior Foreign Affiliates)."

Article III, Section 1:

Revise first thirteen words of second sentence as follows:

"The resignation of a Member, Junior Member, *or* Associate Member (or Junior Foreign Affiliate) . . ."

Article III, Section 2:

In the first sentence, insert the word "or" before "Associate" and delete "or Junior Foreign Affiliate."

To restrict the time during which Student Associates may continue in that status:

Article I, Section 9:

Change the last sentence as follows:

"A Student Associate may remain such until December 31 of the year (following the year) in which he ceases to be in university residence as a student."

Nominees for Institute Officers in 1950

Pursuant to the provisions of the Bylaws as amended, herewith are printed short biographical sketches of the nominees on the official ticket for President, Vice-Presidents, and Directors for the Institute year 1950.

Chairman of the nominating committee of eighteen members is H. Y. Walker.

As provided in the amended Bylaws, 25 Members or Associates may transmit to the Secretary's office "any complete or partial ticket of nominees." If received prior to Sept. 1, a letter ballot will go to all members, containing both the official ticket and any supplementary nominations. If no supplementary nominations are received, according to the amended Bylaws, no letter ballot will be printed and the nominees on the official ticket "shall be declared duly elected at the meeting of the Board of Directors in November."

FOR PRESIDENT AND DIRECTOR

Donald H. McLaughlin, president of the Homestake Mining Co., has served his profession, and the Institute, long and well. A lot of study, traveling, and hard work have filled his 57 years. He graduated from the University of California in 1914, and took his doctorate from Harvard three years later. After two years in the Army, he came back to begin a stellar career. In 1920 he joined Cerro de Pasco and soon after, as chief geologist, was directing the world's second largest geological department.

From 1925 to 1941 he was a professor of mining engineering and mining geology at Harvard, until called to the University of California at Berkeley to serve as dean. During these years, he maintained a consulting practice, serving Homestake and mining organizations throughout the world. Dean McLaughlin became vice-president and director of Cerro de Pasco in 1943. Two years later, he took over the leadership of Homestake. At AIME, Dr. McLaughlin headed the first Committee on Geophysics, and has served on the Mining Geology and Papers and Publications Committees.

FOR VICE-PRESIDENT AND DIRECTOR

Andrew Fletcher is president and treasurer of the St. Joseph Lead Co., and vice-president and treasurer of the AIME. He's a New Yorker, and was 54 last Feb. 6. Mr. Fletcher first worked as a shipyard mechanic in Wilmington, Del., after graduation from Yale's Sheffield Scientific School. Within a short eight years he headed the Fletcher Shipyard in Hoboken, N. J. Maintaining an interest in St. Joe, he became a trustee in 1921, and has been on its executive committee since 1922. Mr. Fletcher is also chairman of the board of the Industrial Hygiene Foundation of America.

Robert W. Thomas, a director of the Institute from 1944 to 1947, and a vice-president since the latter date, has been an engineer for 37 years. He is 63, and general manager for the Nevada Consolidated Copper Co.

Born in St. James, Minn., he graduated from the University of Kansas in 1911. Beginning with the Ray Consolidated Copper Co. as a junior engineer, he moved steadily upward, became superintendent of mines in 1924, and latterly has been general manager at Ray.

FOR DIRECTOR

Harold Decker, 45-year-old petroleum engineer, is assistant manager of the Pan American Production, Pipe Line, and Gas Co. in Houston, Texas. Born in Chicago, he graduated from the University of Oklahoma in 1925. Since then he's been associated with a total of six oil firms, including the Skelly Oil Co. in Tulsa and the Seaboard Oil Co. of Delaware, where he was production superintendent for four years.

Francis B. Foley, superintendent of research for the Midvale Co., Philadelphia, began his metallurgical career with the Company back in 1905, serving there for twelve years. A year of teaching at the University of Minnesota was followed by various activities, including research work with the Bureau of Mines, and collaboration with the late, famed Dr. Henry Marion Howe. In 1926 he rejoined Midvale, assuming his present job. Mr. Foley, a graduate of Girard College, is 61.

Edward C. Meagher, a mining engineer, and president of United Engineering Trustees, Inc., was born in Hoboken, N. J., on Oct. 2, 1897. He attended Columbia University, taking a B.S. degree in 1917, and four years later, an E.M. from the School of Engineering. Mr. Meagher's entire professional career has been spent with the Texas Gulf Sulphur Co. He began there in the sales department in 1921, and is now the firm's treasurer.

Charles Van Ormer Millikan, chief petroleum engineer for the Amerada Petroleum Corp., Tulsa, Okla., has been active in the Petroleum Division since its formation, and was its Chairman in 1930.

Mr. Millikan, 53, is a native Oklahoman and a graduate of Oklahoma A&M. He served in the Navy during World War I, returning to take his M.S. degree from the University of Pittsburgh in 1920. After gathering experience in the Appalachian oil fields for two years, he returned to Oklahoma to join Amerada. He was awarded the Institute's Anthony F. Lucas Gold Medal in 1944.

Howard I. Young, 60, president and general manager of the American Zinc, Lead and Smelting Co. in St. Louis, has spent most of his career in the mining industry. He attended Springfield Business College, joined the firm he now heads in 1908, assuming charge of Missouri mining operations six years later, and becoming president and general manager in 1930. He has been president of the American Mining Congress and the American Zinc Institute.

Gail F. Moulton is a geologist for the Chase National Bank in New York, and a Vice-Chairman of the Petroleum Division, AIME. He is 51, and a graduate of the University of Chicago. Mr. Moulton has 31 years of experience in the petroleum world, formerly headed the petroleum section of the Illinois State Geological Survey, and is a prolific writer in his field.

Division Nominations for 1950

Following are the names of those nominated by the Nominating Committees of the various Divisions for officers for the coming year. In general, the bylaws of each Division provide for additional nominations by petition:

Coal Division: Chairman, Carroll F. Hardy; Chairman-elect, Carroll A. Garner; Executive Committee (until 1953), A. Lee Barrett, Claude P. Heiner, Richard H. Swallow.

Extractive Metallurgy: Chairman, Carleton C. Long; Chairman-elect, Oliver C. Ralston; Secretary, T. D. Jones; Executive Committee (until 1953), Russel B. Caples, A. C. Loonam.

Industrial Minerals: Chairman, Richard M. Foose; Secretary-Treasurer, G. Richards Gwinn; Eastern Vice-chairman, John H. Melvin; Southeastern Vice-chairman, Arthur J. Blair; Rocky Mountain Vice-chairman, Jack C. Pierce; Western Vice-chairman, George D. Dub; Canadian Vice-chairman, Elwood S. Moore; Executive Committee (until 1953), Ian Campbell, Joseph L. Gillson, Stanton Walker.

Institute of Metals: Chairman, Maxwell Gensamer; Senior Vice-chairman, Robert M. Brick; Vice-chairman, Henry L. Burghoff; Secretary, E. O. Kirkendall; Executive Committee (until 1953), William M. Baldwin, Jr., Paul Adam Beck, Alexander Squire.

Iron and Steel: Chairman, H. K. Work; Vice-chairmen, Roy A. Lindgren, Alvin H. Sommer, William A. Steele; Executive Committee (until 1953), Karl L. Fetters, D. L. McBride, George B. McMeans.

Mineral Economics: Chairman, Charles H. Behre, Jr.; Vice-chairmen, Clayton G. Ball, Richard J. Lund, Charles White Merrill; Secretary-Treasurer, Joseph A. Corgan; Executive Committee (until 1953), Simon D. Strauss, W. W. Mein, Jr., and R. J. Bradley.

Mineral Industry Education: Chairman, Allison Butts; Vice-chairman, Harry H. Power; Executive Committee (until 1953) James D. Forrester, John R. Spielman, J. W. Stewart.

Minerals Beneficiation: Chairman, Grover J. Holt; Associate Chairman, Raymond E. Byler; Regional Vice-chairmen, Edwin H. Crabtree, Jr., Donald W. Scott; Secretary-Treasurer, Will Mitchell, Jr.; Committee Chairmen—Membership, James A. Barr, Jr.; Papers and Publications, M. D. Hassialis; Program, Raymond E. Byler; Education, S. R. B. Cooke; Concentration, Milton LeBaron; Materials Handling, Stanley D. Michaelson; Crushing and Grinding, Fred C. Bond; Solids-Fluids Separation, F. W. McQuiston, Jr.; Operating Control, F. M. Lewis; Solution & Precipitation, Max W. Bowen; Pyrolysis & Agglomeration, Fred D. DeVaney; Richards Award, E. H. Rose, J. F. Myers; Symposium, A. F. Taggart; Nominating, T. B. Counselman.

Petroleum Division: Chairman, John E. Sherborne; Vice-chairman, Paul Andrews; Executive Committee (until 1953), R. W. French, R. C. Earlougher, John R. McMillan.

Results of the Balloting on Increased Dues

Ballots mailed 11,618

Branch	Yes	No	Percent Yes
Mining	2,258	651	77.5
Metals	1,339	366	78.5
Petroleum	1,306	357	78.5
Other	500	146	77.4
Total	5,403	1,520	78.2

What Went on at Recent Local Section Meetings

SECTION	DATE	ATTENDANCE	SPEAKER, AFFILIATION, AND SUBJECT
Arizona, Morenci Subsection	April 12	33	William Distler, "Proverbs for the Young Engineer." J. E. Skipper on the Morenci power plant and the future of the gas turbine.
Black Hills	May 6	90	Joint meeting, Woman's Auxiliary and Student Associates from S. Dak. School of Mines & Technology. J. V. N. Dorr, The Dorr Co., on early development of Dorr equipment in Black Hills.
Boston	May 2	72	Joint meeting with Woman's Auxiliary. Seville R. Davis, American editor, Christian Science Monitor. "Analysis of Postwar U. S. Foreign Policy in Europe."
Carlsbad Potash	May 12	52	J. Harlan Johnson, Colorado School of Mines, comments on International Geological Congress.
Columbia	May 14	120	Third Annual Northwest Industrial Minerals Conference.
Cleveland	May 12	.....	Harry A. Schwartz, National Malleable & Steel Castings Co. "Correlation of Physical Properties with Chemical Composition in Low Alloy Cast Steels."
Detroit	May 16	.....	A. C. Cooley, General Electric Research Lab. on metallic sheet.
Mid-Continent	April 9	100	John T. Hayward, Barnsdall Oil Co., on unique design for offshore drilling structures.
Montana	April 26	130	R. H. Townsend, Anaconda Copper Mining Co., on ferromanganese operations.
Montana	May 27	.....	Joint meeting with Last Chance Gulch Mining Assn. W. R. Wade, Rainbow Mining Co., on the Marysville district.
New York	May 18	75	J. D. Doherty, office of synthetic liquid fuels, Bureau of Mines, "Synthetic Oil—Security for the Future."
Ohio Valley	May 18	22	Film, "Ohio and its Mineral Resources." Progress report on AIME Mid-Year Meeting.
Pennsylvania-Anthracite	April 22	195	S. H. Ash, chief, safety branch, Bureau of Mines, on anthracite flood-prevention project.
St. Louis	April 22	86	J. G. Evans, Gardner-Denver Co., on mining experiences in South Africa.
Utah	April 21	44	Clayton Wolf, Univ. of Utah engineering experiment station, on use of noncoking coal in metallurgical processes.

Engineering Index Volumes Wanted

Copies of the bound volumes of Engineering Index from 1928 to date are needed by various libraries and organizations, both in this country and abroad. If you have volumes that you do not need, please get in touch with Ralph H. Phelps, director, Engineering Societies Library, 29 West 39th St., New York City 18.

The Drift of Things

The Referendum

One may look at the results of the referendum on increased dues in one of two ways. It may be considered reassuring that three fifths of the AIME members qualified to vote returned their ballots, and that four out of five of them voted for the increase although it definitely meant an out-of-pocket expense to them for the next three years. Also, it is good to know that all three Branches—Mining, Metals, and Petroleum—show the same four-to-one ratio in favor of increased dues.

But speaking as Secretary of the AIME, we choose to look at the vote with something less than complete satisfaction. Serious thought should, we believe, be given to the fact that some 1500 members do not seem to think the service they are getting, or are likely to get in the future, is worth more than the $15 or the $10 that they have been paying for the the last three decades, in spite of the acknowledged greatly increased cost of practically everything. Also, in spite of what we are assured was an excellent percentage of returns, the fact remains that about two fifths of the Institute membership was too busy or not sufficiently interested to vote at all. Although they were not actively against the proposed increase in dues, they did not support it, even to the extent of making a couple of check marks, signing their name, and dropping a postal card into the nearest letter box.

Unquestionably, much more work must be done in making the Institute what its members want it to be. Most tangible of the services that can be improved, of course, are the publications—monthly journals and books, and the meetings—annual, mid-year, Divisional, and Local Section. But also the officers, Directors, and headquarters staff of the AIME must get closer to the members, must think about and talk over each others' problems, and must discover what new fields offer promise of better service to members.

We feel that a good start has been made, but far more must be accomplished in the next three years. At that time another referendum will be taken, and it is hoped that in the meantime it will be possible to increase advertising income, the sale of books, and the number of members sufficiently to make a return to the current dues schedule possible. Other avenues of income may also be developed, or methods of cost cutting devised, so that the standard of services to AIME members can be maintained, or even expanded, even though prices will not have retracted to the prewar level.

Those of us whose responsibility it is to run the Institute must, in the next three years, justify our stewardship. But the AIME is a co-operative enterprise, and the best results can only be secured if the members at large also will aid in every way they can to secure and prepare more and better papers, and to hold more interesting meetings.

Reviewing the First Six Months of the New Journals

At the Board meeting last September, approval was given for the three new journals whose publication began with the issues for January 1949. According to the minutes of that meeting, "Section one of each of the journals would be devoted to advertising and editorial matter of specific interest to the individual Branch and to be secured, edited, and wholly under the control of the Branch council or editor. Section two would be common to all three journals and would consist of feature articles, shorter material, and professional news prepared and edited at Institute headquarters but of a wide interest and character to be approved by each Branch council or editor. Section three would consist of technical papers of interest to the respective Branches, as now published in the Technologys." It was planned at that time that Section one of the three journals would average about as follows, as to number of pages per issue: Mining, 48; Metals, 16; Petroleum, 32. Section two would average about 24 pages for each of the journals. The actual number of pages for the first half year has not been greatly different from these estimates. Section three averages were: mining, 37; metals, 65; and petroleum, 28 pages.

At the May Board meeting, proposals of the three editors were advanced to reduce the size of Section two (the All-Institute section) to an average of about eight pages per month. This would involve elimination of all personals and obituaries from the All-Institute section and assigning them to Section one, according to Branches. The material still to be put in Section two would include reports of Board meetings, a page or two of the Drift of Things, the calendar of coming meetings, a summary table of Local Section meetings, a list of the titles of all technical papers published in the three journals with a definitive sentence as to the subject covered, a list of those applying for membership (though this might be split according to Branches and published in Section one), publicity regarding Annual and Mid-Year meetings, short book reviews of general interest, brief Woman's Auxiliary news, and short biographies of the President and new Directors each year. An occasional feature article might be used if space permitted. The annual reviews, which bulked so large in the March issue, would be split up and published only in the journal covering their specific field.

Those present at the Board meeting were, of course, the more mature members of the Institute, and they expressed considerable opposition to further condensation of the All-Institute section, particularly as to elimination of the personals. Their interests are naturally broad, and their friends and acquaintances fall into all three Branches. They pointed out that the present scheme of publishing has met with almost unanimous approval and they urged that no further change be made until at least one full year has been completed. In the meantime, however, the editors will welcome comment from members as to the type of material they like in the present journals, and what classes, if any, they do not find of interest.—*E. H. R.*

Mid-Year Meeting News

Governor Lausche

A Message from the Governor of Ohio

"I am happy to learn that the 1949 Mid-Year meeting of your Institute is going to be held in Columbus, Ohio, the week of September 25th.

"It is a pleasure and privilege to welcome the officers, members, and guests of your organization to our Capital City.

"It might interest you to know that Ohio is one of the leading mineral producing states, with coal, oil and gas, limestone, clay, glass sand, salt, gypsum, and numerous other minerals all mined within our borders. Ohio is also rich in scenic attractions and historical lore.

"I am, therefore, pleased that you have chosen our state as the place for your meeting, and I know that in the friendly atmosphere of Columbus your sessions will be both enjoyable and educational."

FRANK J. LAUSCHE,
Governor, State of Ohio

A Message to Members:—

The Mid-Year Meeting of the Institute, scheduled for Columbus during the week of September 25, 1949, will afford a splendid opportunity for members and their friends to participate in an outstanding technical program. There will be papers and conferences on current problems of industry, management, and technical education in the mineral technology field; and inspection trips to some of the nation's finest industrial and research plants.

A most cordial welcome has been extended to all Institute members to visit Columbus on this occasion by the Governor of Ohio, the Mayor of Columbus, and the officers of the great industrial, research, and educational institutions, as well as by the Ohio Valley Section of the Institute.

The AIME Directors hold their September meeting at Columbus on September 27, with representatives of the Sections and Divisions present to discuss the program and progress of the Institute. The social functions planned for the ladies, as well as the members, will add greatly to the pleasure of the meeting. Adequate hotel accommodations are assured.

On Friday, Sept. 30, the Southern Ohio Section of the Open-hearth Committee, AIME, will begin a two-day meeting, also at Columbus, so many members will find that their time can be profitably occupied for the entire week.

The Mid-Year Meeting presents a splendid opportunity for many who could not be at San Francisco to participate in an important national gathering of mining and petroleum engineers and metallurgists for which most diversified programs have been arranged.

L. E. YOUNG,
President, AIME

Women Plan Gala Meeting

Several hundred women from all parts of the country will arrive in Columbus on September 24 with their engineer spouses, and the Columbus Section of the Woman's Auxiliary, AIME, will play the gracious hostess during the Mid-Year Meeting. Mrs. Elmer R. Kaiser, 2406 Brixton Rd., Columbus, general chairman of the ladies' committee, has been busy arranging the entertainment.

Following the All-Institute luncheon on Monday afternoon, the ladies have scheduled a sightseeing trip through Ohio's capital city, winding up the day with a tea at the home of the president of Ohio State University. Tuesday will feature a visit to the Heisey Glass Co. at Newark, Ohio, lunch at the Granville Inn, and then a tour of the plant where the new Lustron houses are made. A fashion show and luncheon at the Maramor, famed Columbus restaurant, will be Wednesday's high spot, but the ladies will go higher that evening to dine with their husbands atop a forty-story skyscraper in the heart of the city. A romantic nocturnal visit to the local observatory is planned for later that night, with a planetary display on the agenda.

Columbus's Mayor Welcomes the AIME

"Columbus appreciates the honor and privilege of playing host to the American Institute of Mining and Metallurgical Engineers.

"Columbus is the heart of a great state. It is Ohio's capital city. Meeting in Columbus is traditional, for hundreds of conventions are held in our city each year. There are many fine hotels and restaurants to accommodate visitors.

"It's easy to come to Columbus. Our city is conveniently accessible to the country's principal metropolitan centers by air, rail or highway. One half of the nation's population resides within a 500 mile radius of Columbus.

"We urge you to attend your mid-year meeting. We know you'll enjoy your stay, although brief, in Columbus."

JAMES A. RHODES, Mayor,
City of Columbus, Ohio

Mayor Rhodes

XUM

Part of the broad and beautiful campus of Ohio State University in Columbus, where 2600 educators serve a student body numbering 24,000. This is but one of the 54 colleges and universities which make Ohio one of the nation's best educated sections.

Ohio the Great

Ohio, native state of eight Presidents, seventh in rank among the states producing industrial minerals, leading the world in rubber, steel, and clay products, will play host to the AIME in September. Ohio is the Iroquois word for "great." Ohio's great, and our Mid-Year Meeting will be the same.

There'll be plenty of vacationing to do in the Buckeye State when technical sessions are over. Five hundred and thirty miles of rivers and a 230-mile frontage on Lake Erie furnish scenic beauty, and direct commerce routes with the world. Great steel and other industries along the waterways move observers to label Ohio "The Ruhr of America." A storehouse of minerals lies below the fertile farmland, and 117,000 businesses operate atop it. Columbus, the state capital, with the Scioto River winding like a ribbon through her hair, awaits Mr. and Mrs. AIME.

Ohio is mostly farmland, but oil derricks hold up the sky, and the world's largest sandstone quarry (right) is in S. Amherst. The soil over which the pioneers traveled in 1788 now yields a rich harvest of food, and the minerals vital to commerce.

In the Buckeye State, heavy industry joins with ante-bellum charm, providing lifeblood for the world's commerce, and pleasure for visitors. Up and down the Ohio and Muskingum rivers flow the iron ore, coal, and limestone which keep the blast furnaces going.

Among the Student Associates

Mackay Grads Feted by Reno Section

The twenty-two members of the graduating class at the University of Nevada's Mackay School of Mines were the honored guests, on May 5, at a luncheon meeting of the Reno Section, AIME. Chairman A. C. Johnson presided, and called upon Jay A. Carpenter to introduce the graduates individually.

All twenty-two graduates are Student Associates of the AIME, credit for this fine record going to H. B. Chessher, Sr., chairman of the Reno Section's membership committee. Alberto Barrios, retiring president of the Crucible Club, addressed the gathering, and then went on to provide fine entertainment, singing and accompanying himself on the guitar.

Lehigh University

The Howard Eckfeldt Society met for the last time this year on May 19, viewing a film and electing officers for next year. The film was a Phelps Dodge Copper Co. presentation, showing mining and milling operations at Bisbee, Ariz.

The men who'll pilot the Society through the next year are: President Robert L. Smith; Vice-President Robert A. Limons; Treasurer Joseph A. Holmes; and Robert E. Nolan, Jr., Secretary.—*Robert E. Nolan, Jr., Secretary.*

Calendar of Coming Meetings

JULY

7 Reno Branch, Nevada Section, AIME.
9-23 Fourth Empire Mining and Metallurgical Congress, Great Britain.
13 El Paso Metals Section, AIME.
13 Southwestern New Mexico Section, AIME.
13-15 American Society of Civil Engineers, summer convention, Mexico City.
15-24 Pan-American Engineering Congress, Rio de Janeiro.
19 Gulf Coast Section, AIME.
25 Alaska Section, AIME.

AUGUST

22-26 AIEE Pacific general meeting, Fairmont Hotel, San Francisco.
26-Sept. 10 Engineering & Mining Exhibition, London, England.
Aug. 17-Sept. 6 United Nations Scientific Conference on the Conservation and Utilization of Resources, Lake Success, N. Y.

SEPTEMBER

25-28 American Mining Congress, Metal Mining Convention, Hotel Davenport, Spokane, Wash.
25-28 Mid-year Meeting, AIME, Neil House, Columbus, Ohio.
29-30 ASME, fall meeting, Erie, Pa.
29-Oct. 1 Colorado School of Mines, 75th anniversary celebration.
Sept. 30-Oct. 1 Southern Ohio Section of Open Hearth Committee, AIME, fall meeting, Deshler-Wallick Hotel, Columbus.

OCTOBER

5-7 Petroleum Branch, AIME, fall meeting, Plaza Hotel, San Antonio, Texas.
13-14 Texas Mid-Continent Oil and Gas Association, annual meeting, Rice Hotel, Houston.
14 Eastern Section, Open Hearth Committee, Iron and Steel Division, annual all-day fall meeting, Warwick Hotel, Philadelphia.
14 Southwestern Section, Open Hearth Committee, Iron and Steel Division, Kansas City, Mo.
17-19 Institute of Metals Division, AIME, fall meeting, Allerton Hotel, Cleveland.
17-23 AIEE, 1949 Mid-West meeting, Netherland Plaza, Cincinnati.
20-21 Petroleum Branch, AIME, Elks Club, Los Angeles.
24-28 Thirty-seventh National Safety Congress and Exposition, Chicago.
26-27 Joint Fuels Conference, ASME-AIME, French Lick Springs Hotel, French Lick, Ind.
28 Pittsburgh Section of Open Hearth Committee and Pittsburgh Section, AIME, annual fall meeting, William Penn Hotel, Pittsburgh.
28-29 ECPD, annual meeting, Edgewater Beach Hotel, Chicago.

NOVEMBER

1-5 Pacific Chemical Exposition, California Section, American Chemical Society, San Francisco Civic Auditorium.
2-4 American Society of Civil Engineers, fall meeting, Washington, D. C.
7-10 AIChE, annual meeting, Pittsburgh, Pa.
9-11 Industrial Minerals Division, AIME, Tampa, Fla.
12-14 Geological Society of America, annual meeting, Hotel Cortez, El Paso.

DECEMBER

7 American Mining Congress, Annual Business Meeting, New York City.
8-10 Seventh Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.

JANUARY 1950

18-20 American Society of Civil Engineers, annual meeting, New York.
30 AIEE, winter meeting, New York.

FEBRUARY 1950

10 Southwestern Section, Open Hearth Steel Committee, Iron and Steel Division, St. Louis, Mo.
12-16 Annual Meeting, AIME, Statler (Pennsylvania) Hotel, New York City.

APRIL 1950

2-4 Annual conference, National Open Hearth Committee, Iron and Steel Division, Cleveland, Ohio.
10-12 Open Hearth Conference, and Blast Furnace, Coke Oven and Raw Materials Conference, Netherland Plaza Hotel, Cincinnati.
19-21 American Society of Civil Engineers, spring meeting, Los Angeles.

DECEMBER 1950

7-9 Eighth Annual Conference, Electric Furnace Steel Committee, Iron and Steel Division, AIME, Hotel William Penn, Pittsburgh.

University of Nevada

At the April 27 meeting of the Mackay School of Mines' Crucible Club, Mr. Zadra, of the Rare Metals Station of the Bureau of Mines in Reno, presented, for the first time, his paper on the electrolytic deposition of gold from activated charcoal. The students found the session most interesting and educational.

The Club then went on to elect officers for next year. Fred Muller is the new President, with John Cunningham, Walter Johnson, and Harry Varischetti serving as Vice President, Secretary and Treasurer, respectively.

Club members can now look back on a highly successful semester of activities. W. E. Wrather, USGS head, and former AIME President, addressed the group in February, and the March gathering heard a report from President Barrios on the AIME Annual Meeting in San Francisco. Since the first of the year, the Club has sponsored several movies for students and the public, including films on the natural resources of Nevada, block caving methods at the Emma Nevada mine in Kimberly, and one on the various types of Marion shovel in operation. The alumni paper, "The Mackay Miner," was published during the first week of May, and mailed to alumni, former students, and friends of the club.—*Walter B. Johnson, Secretary.*

University of New Hampshire

An aerial field trip, aimed at studying the glacial features of Illinois, and made last summer by the students of the University of Illinois, was described to University of New Hampshire Student Chapter members at their regular April meeting. D. H. Chapman, associate professor of geology at New Hampshire, described the airborne venture, which he had directed, and illustrated his talk with excellent color slides.

New officers for the coming year were elected at another April meeting. New Chapter President Lawrence W. Wakefield is ably supported by Vice-President Carl A. Lein; Secretary-Treasurer Mrs. Isabelle A. Kerdack; and Corresponding Secretary Livingston Chase.—*Marston Chase, Corresponding Secretary.*

News of AIME Members

Marshall B. Ames was transferred early in January by the Corps of Engineers from the Alaska district to the Walla Walla, Wash., district.

E. W. K. Andrau expects to do considerable research and prospecting for uranium in the Rocky Mountain area. The E. W. K. Andrau Enterprises has opened an office in Lander, Wyo., where it is expected that Dr. Andrau will in the near future do considerable geological work in addition to some drilling this year.

Murray R. Arrowsmith can be found in Kimberly, Nev., where he is working as a geologist for the Consolidated Coppermines Corp.

L. J. Barraclough, who is reached at the Disergarh Post Office, Burdwan District, W. Bengal, India, has been elected president of the Mining, Geological and Metallurgical Institute of India.

Ralph C. Beerbower, former district manager of the Goodman Mfg. Co., has taken the post of assistant to the superintendent of the H. C. Frick Coke Co., West Leisenring, Pa.

Chas. H. Behre, Jr., returned late in April from Rangoon, where, as representative of Behre Dolbear & Co., mineral advisers to the Burma Union Government, he had been discussing general plans for mineral development. The trip involved a round-the-world flight. He left to resume field work in Mexico on May 15, and on June 7 received an honorary degree of Doctor of Science from Franklin and Marshall College, Lancaster, Pa.

Josef W. J. Bercher is assistant division manager of the Texas Eastern Transmission Corp., P. O. Box 32, Downingtown, Pa.

Bernard Beringer, former assistant general manager of Randfontein Estates G. M. Co., is now mine manager of Palmiet Chrome Mines Ltd., P. O. Matooster, Rustenburg, Transvaal, S. Africa.

Charles W. Campbell has changed from the engineering department to the production department of Mina Tiro General, Charcas, S.L.P., Mexico, and is now shift boss at the property.

K. P. Campbell, working for the American Smelting and Refining Co., has been transferred from Chihuahua, Mexico, to the Company's general engineering department at El Paso, Texas.

William J. Coulter, Jr., is working as a miner for the Bunker Hill and Sullivan Mining and Concentrating Co. His address is P. O. Box 353, Kellogg, Idaho.

Orville R. Dahlberg, since graduating from the University of Wisconsin, has been employed by the Oliver Iron Mining Co. as a mining engineer on a training program, intended to acquaint future operators and engineers of the company with the various operations that comprise the company as a whole. Periods of varying lengths are spent under the different departments, such as engineering, special exploration, budget control, shops, grading, sampling and safety.

Rene Engel

Rene Engel, geologist and chemical engineer, recently became associated with **Florent H. Bailly,** petroleum engineer and geologist, founder and president of Oil Properties Consultants (geology and engineering) and Petroleum Engineering Associates (laboratory studies), both of Pasadena, Calif. Under the names of Petroleum Industry Consultants, Cuba, and Petroleum Industry Consultants, Venezuela, this association is extending its services from branches located respectively in Havana and Caracas. Dr. Engel still retains his post as curator of mineralogy and petrology at the Los Angeles County Museum.

Paul B. Entrekin

Paul B. Entrekin, former vice-president and manager of Bethlehem Chile Iron Mines, became manager of the Bethlehem Steel Company's mining division in May. A Lehigh graduate, Mr. Entrekin started with Bethlehem in 1925 as an engineer in the mining department. He was transferred to the Cornwall mine in 1926 to service successively as plant engineer, mine superintendent, and assistant manager. In 1941 he went to El Tofo, Chile, as mine superintendent and assistant manager of Bethlehem Chile, a Bethlehem Steel subsidiary, becoming manager and vice-president in 1944.

Lloyd L. Connell writes that his connection with the Stoker Manufacturers Association terminated on April 1 and that he is now with the Diamond Chain Co., Indianapolis, Ind. Following completion of his current period of training, he expects to be assigned to a territory as sales representative.

John M. Davis can be reached at the Western Machinery Co., 231 Healey Bldg., Atlanta 3, Ga. He had worked for the Phosphate Mining Co. in Florida.

Joseph M. Downey, formerly metallurgist at the Leadville milling unit of the American Smelting and Refining Co., is now a miner at the Kokomo Victory mine of the Company.

John R. Drenan has been appointed superintendent of the fluorspar division of the United States Coal and Coke Co. at Mexico, Ky., effective May 1.

L. E. Young, guest of honor at St. Louis Section—Missouri School of Mines Student Chapter banquet on May 14, with St. Louis Chairman Herbert Franke and Mrs. Franke.

L. E. Young, President of the AIME, spoke before the Missouri School of Mines Student Chapter on May 14. He discussed briefly technical assistance to foreign countries and then spoke at length on potash mining, illustrating his talk with slides and maps. The Student Chapter reports that Dr. Young's wide experience, coupled with natural speaking ability, gave a comprehensive picture of this type of mining, and members of the Chapter feel that this was the most important meeting in the history of the Chapter.

Gilbert C. Davis acted as manager of the Stag Canon branch of the Phelps Dodge Corp. from 1929 to 1939 when he was transferred to the Morenci branch where he was in charge of operations until 1946. At that time he was transferred to Douglas, Ariz., as director of labor relations, and continued in that capacity until his retirement on March 1. To go back thirty odd years, Mr. Davis went from Denver to the Rock Springs district to open a new coal mine for the Colony Coal Co. at Dines, Wyo., and was in charge of operations until 1927 when he moved to Mt. Harris, Colo., and for the next two years was general manager of the Colorado & Utah Coal Co. as well as the Colony Coal Co.

G. Dessau, an Italian mining engineer, who, after having been taken to India as a prisoner of war, was later allowed to work there and was in charge of the geophysical section of the Geological Survey of India from the start of that section, has now returned to Italy. He has again taken up service with the Italian Colonial Administration and has been attached to the Geological Survey of Italy.

O. J. Egleston has retired as vice-president and consulting engineer for the U. S. Smelting Refining and Mining Co. after 46 years with the Company and its predecessor. **A. B. Marquand** has also retired as vice-president and manager of metal sales after 31 years with the concern.

Andrew Fletcher, president of the St. Joseph Lead Co., and vice-president and treasurer of the AIME, delivered the commencement address at the Missouri School of Mines and Metallurgy, Rolla, on May 31. At the same time the University of Missouri conferred upon him the degree of Doctor of Engineering.

Milton H. Fies has been appointed a consulting engineer to the Office of Synthetic Liquid Fuels, Bureau of Mines. He will continue as part time manager of coal operations for the Alabama Power Co. Under Dr. Fies's supervision, the Alabama Power Co. is collaborating with the Bureau of Mines in a second field-scale experiment in the underground gasification of coal at Gorgas, Ala. A seam of coal there recently was ignited under carefully controlled conditions to determine the feasibility of using the gases thus produced as a source of fuel for boilers and as a raw material for making synthetic oil and gasoline.

Glenn H. Fritz left his job with the Anaconda Copper Mining Co. last December and is now employed by the Joy Mfg. Co. as a sales trainee.

J. Porter Gardner, Jr., formerly field ventilation engineer for the Joy Mfg. Co. at their New Philadelphia, Ohio, plant, was transferred on Jan. 1 to Joy's Chicago district sales office as sales representative specializing in fan sales.

Dion L. Gardner has moved his consulting office in geology and engineering to 1815 W. Chapman, Orange, Calif., c/o Association Laboratories. His office was in Santa Ana.

Fred E. Gray is living at the Asbury Apartment Hotel, 2505 W. 6th St., Los Angeles 5. He is assistant general manager of the Coronado Copper and Zinc Co.

I. G. Grossman, formerly at the department of geology at the University of North Dakota, is now with the petroleum economics branch of the Bureau of Mines in Washington, D. C.

Julius B. Haffner has been elected second vice-president of the Bunker Hill and Sullivan Mining and Concentrating Co. and **Donald H. McLaughlin** becomes a director of the Company.

Alfred S. Harvey, since graduation from the Missouri School of Mines and Metallurgy last June, has been quarry foreman for the U. S. Gypsum Co. at the Fort Dodge plant. He can be reached at 1111 S. 18th St., Fort Dodge, Iowa.

John S. Hemphill is now associated with C. A. Venezolana de Cementos, Caracas, Venezuela.

James M. Hill, formerly geologist with the Union Carbide and Carbon Co., has opened his office as a consulting mining geologist at 182 N. Court St., Tucson, Ariz.

Arne Hofseth is one of two Norwegian technicians who will spend six months in the United States studying mining methods and equipment which might be adapted for use in mine operations in Norway. They are particularly interested in modern methods of open pit mining, equipment used for milling and transporting ore, and American methods of pelletizing iron ore. The Bureau of Mines is co-operating with ECA's technical assistance division in arranging the studies.

John A. Johnson is supervisory engineer of the Duluth office of the Health and Safety Division of the Bureau of Mines.

Werner O. Joseph, upon graduation from the University of Chile, became assistant mill foreman of Cia. Minera Punitaqui in Ovalle, Chile.

Francis R. Joubin, for twelve years on the exploration and mine staff of Pioneer Gold Mines of British Columbia, and more recently engaged as their Eastern Canada representative, has been granted a leave of absence allowing him to assume charge of exploration projects for other companies. He will be retained as Pioneer's eastern adviser on exploration, and will continue to make his headquarters at the Pioneer company's offices at 510 Concourse Bldg., 100 Adelaide St., W., Toronto, Ont.

Nicholas N. Kohanowski, formerly with Cie. Aramayo de Mines en Bolivie, has returned to the States and accepted the post of assistant professor in the department of geology at the University of North Dakota, Grand Forks.

Emerson C. Lane, has gone to San Juancito, Honduras, as metallurgist for the New York and Honduras Rosario Mining Co.

H. F. Lynn informs us that he is now associated with the Southwestern Engineering Co., 4800 Santa Fe Ave., Los Angeles 11, Calif. He had been with the Western-Knapp Engineering Co.

Mark C. Malamphy, consulting geophysicist, formerly of Little Rock, Ark., and W. G. Garlick, consulting geologist of Lusaka, Northern Rhodesia, have incorporated under the firm name of Mark C. Malamphy & Co., Ltd., consulting geologists and geophysicists with offices in Mufulira, N. Rhodesia. Mr. Malamphy has been engaged in geophysical work in the United States, Canada, and South America since 1926, and in the Union of South Africa, the Rhodesias, and the Belgian Congo since 1946. Mr. Garlick has been doing geological work in South and Central Africa for about twenty years. The new firm's address is P. O. Box 209, Mufulira, N. Rhodesia.

Charles A. Marr is working for the St. Joseph Lead Co. at Bonne Terre, Mo., as a mining engineer.

Robert R. Mates, since school days at the University of Utah, has been employed by the Kennecott Copper Corp., Arthur, Utah, as a research engineer and by the Bureau of Mines at Salt Lake City as a metallurgist.

J. L. McCluggage is a mining engineer with the Kamunting Tin Dredging Co., Taiping, Perak, Malaya. He had held the same post with the Rawang Tin Fields, Ltd.

C. E. McManus has been appointed assistant to the general manager of the Minnesota mines of The M. A. Hanna Co.

Wilson D. Michell, after spending two years in French Morocco as geologist for the Societe Nord-Africaine du Plomb, engaged in the exploration and development of lead-zinc deposits in the northeastern part of that country, is now working as a geologist for the Resurrection Mining Co. at Leadville, Colo.

Arnold H. Miller, consulting engineer of New York City, has been in Sinaloa, Mexico, on professional work.

F. Stuart Miller has 50 S. Remington Rd., Columbus, Ohio, as a permanent address, but right now he is in Kuala Lumpur, Malaya, as assistant manager of the Pacific Tin Consolidated Corp.

James T. McDonald is working for the Bunker Hill and Sullivan Mining and Concentrating Co. at Kellogg, Idaho, as a surveyor.

Clarence O. Mittendorf is on an ECA mission to Turkey. He can be reached at Ankara in care of the American Embassy.

C. C. Huston

C. C. Huston, former head of the exploration department of Macassa Mines Ltd., has resigned from that post to enter into private consulting practice. His address is 1001-85 Richmond St., W., Toronto.

R. M. Mahoney

R. M. Mahoney is continuing his activities with the United States Vanadium Corp. as manager of industrial relations but has moved his headquarters to Bishop, Calif.

Ivan L. Nichols is working as a metallurgical trainee for the U. S. Smelting Refining and Mining Co. at Midvale, Utah. He had been with the Pacific Bridge Co. in Park City.

C. M. Peters, who left his post as geologist and chief engineer at the Neptune Gold Mining Co. after completing one year, is now working out of San Francisco for the firm of Dames and Moore, who do foundation engineering and soil mechanics. He is their geologist and job engineer on work that consists of testing the soil and formation for foundations of buildings, bridges, and dams.

R. G. Ponsford recently became a member of the Ponsford-Moos Equipment Co., El Paso. He was formerly with the Mine and Smelter Supply Co. and takes to his new post many years of experience specializing in mining, industrial, and shop equipment.

Burton M. Reynolds was appointed mining engineer, Rolla branch, Mining Division, Bureau of Mines, last November, going there from Idaho. He was formerly with the Bureau in College Park, Md. His present assignment is in Little Rock, Ark.

T. A. Rickard, of Victoria, B. C., has been appointed an honorary fellow of the Imperial College of Sciences. Most octogenarians are satisfied to sit back and let the world carry on by itself, but not Dr. Rickard. Last year he published "Historic Backgrounds of British Columbia," and recently his new book, "Autumn Leaves," has appeared.

Ernest R. Rodriguez is working as a mining engineer with the safety branch of the Bureau of Mines with headquarters at Phoenix, Ariz.

John A. Roos is working for the Baroid Sales Division of the National Lead Co. as a mining engineer. His address is Box 265, Belle Fourche, S. Dak.

John G. Reilly resigned as general manager of the Bayard, N. Mex., department of the United States Smelting Refining and Mining Co. on May 21. He will enter the consulting field and will continue to maintain his residence at 407 College Ave., Silver City, N. Mex. Mr. Reilly formerly was managing director of Cia. Real del Monte y Pachuca at Pachuca, Hidalgo, Mexico.

Joseph T. Roe is construction engineer for Dent and Russell Inc., Dantors division, mining, milling, and manufacturing, in Maupin, Oreg.

H. L. Roscoe, vice-president and general manager of Noranda Mines Ltd., who had been resident in Noranda since the beginning of operations, has moved to the head office in Toronto. **R. V. Porritt,** who has served the Company since 1926, for the last ten years as assistant general manager, was appointed manager.

Robert J. Rose has gone to the Union of S. Africa where he can be reached in care of the Messina Development Co., Messina, Transvaal.

Pierre Routhier, fellow of the University of Paris, former head of the geological mission of the office of the Recherche Scientifique Coloniale in New Caledonia, left New Caledonia recently. He and two associates will study the material collected there in the geological

laboratory of the Ecole Normale Superieure, 45 rue d'Ulm, Paris.

Larry Seaman, project manager for the Iron Mines Co. of Venezuela, a Bethlehem Steel Co. subsidiary, has changed his address from Caracas, Venezuela, to Guiria, Estado Sucre, Venezuela, where the Iron Mines Co. is building a port for the transshipping of Venezuelan iron ores.

Henry G. Schuring, formerly connected with La Luz Mines Ltd. at Siuna, Nicaragua, is now mill superintendent of the New Idria Honduras Mining Co., Santa Rosa de Copan, Honduras.

Charles E. Stott, formerly vice-president and general manager of Cia. Minera de Penoles and Cia. Metalurgica Penoles, subsidiaries of the American Metal Co., is at present located in Washington, D. C., as regional specialist with the strategic materials division of ECA, covering Africa.

J. A. Swart, who was general superintendent for the Raymond Concrete Pile Co., on their contract to build the Cardon refinery for the Shell Oil Co., has gone to Chuquicamata, Chile, as assistant job manager with Foley Hermanos on the construction contract to build a new sulphide plant for the Chile Exploration Co.

J. R. Sweet arrived in the States last August from Northern Rhodesia where for the past 4½ years he was in the service of the Roan Antelope Copper Mines, Ltd., Luanshya. He is now general manager for the Tungsten Mining Corp., Henderson, N. C. His residence address is 230 Virginia Ave., Henderson.

E. H. Thaete, Jr., has transferred his headquarters from New York to the New Orleans office of the Freeport Sulphur Co., 1804 American Bank Bldg.

E. L. Thomas, Jr., was graduated in mining engineering from the University of Alabama at the end of the last quarter and will be located in the Birmingham district with the Tennessee Coal, Iron, and Railroad Co.

David W. Tittman graduated from the Missouri School of Mines in January and was then employed by the St. Joseph Lead Co. as metallurgist in the ore dressing research laboratory. He is living at 207 E. School St., Bonne Terre, Mo.

Hale C. Tognoni is working at the Darwin Mines, Darwin, Calif. He had been a student at the University of Nevada.

Marvin J. Udy now spends half of his time with the Vanadium Corp. of America in the development of new processes for chromium and ferroalloys. At the same time he is acting as consulting engineer for the New Jersey Zinc Co. in the electric furnace smelting of Quebec ilmenite, and also for Fabrica Nacional de Carburo y Metallurgia of Santiago, Chile.

Gilfry Ward has been appointed vice-president in charge of sales of the American Manganese Steel Division of the American Brake Shoe Co. He will be located in Chicago Heights, Ill. With Brake Shoe since graduating from Yale in 1928 he has spent many years on both the East and West Coasts with the Amsco sales organization.

H. P. Willard has changed his address from 166 Tomb St., Tiffin, Ohio, to Gabbs, Nev.

J. P. Williams, Jr., chairman of the board of directors of the Koppers Co., Pittsburgh, retired from active management of the company in May. He remains a member of the board and will continue in his capacity as chairman of the board, as well as an adviser on special problems. Actively associated with the Koppers Co., or its predecessors, since 1920, he was manager of the Melcroft Coal Co. until Koppers absorbed it, was elected executive vice-president of Koppers in 1933, and became president in 1939.

John Worcester has been appointed production manager of the National Lead Co., S. A., with headquarters in Buenos Aires, Argentina.

Carl C. Youell is superintendent of the Jewell Ridge Coal Corp. at Oneida, Tenn.

• In the Metals Branch

© *Harris and Ewing*

Robert L. Baldwin

Robert L. Baldwin has been made assistant to G. A. **Wallerstedt,** western district manager for the Hardinge Co., York, Pa. He will assist in sales development, using the Hardinge office at 24 California St. in San Francisco as headquarters. Mr. Baldwin began his career in 1901 as a technician for the American Steel and Wire Co. in Cleveland. He joined the U. S. Steel Corp. in 1912 as a special representative in exploiting, licensing, and selling the Heroult electric steel furnace. When the Heroult basic patent expired in 1920 he joined the Republic Carbon Co., which was acquired fourteen years later by the National Carbon Co. He became sales development manager of the electrode division of that organization, retiring from that post this year to join the Hardinge organization.

Thomas E. Barlow, formerly on the staff of Battelle Memorial Institute, is now sales manager for Eastern Clay Products, Inc., Jackson, Ohio.

Joseph J. Brugman is no longer employed by Idaho Smelting Inc. He is now with the Morley Magnesium Foundries, Box 628, Renton, Wash., as metallurgical superintendent.

Thornton C. Bunch has transferred to Vallejo, Calif., where he is foundry superintendent at the Mare Island Naval Shipyard. He had been working at the Navy Yard at Pearl Harbor.

J. E. Burke, formerly at the University of Chicago, has recently joined the Knolls Atomic Power Laboratory at the General Electric Co. in Schenectady as a research assistant. His new home address is R. D. 1, Ballston Lake, N. Y.

Hans I. Elvander, Box 3616, Degerfors, Sweden, is assistant to the general superintendent of Degerfors Jernverks AB.

Matthew A. Hunter is retiring as dean of faculty after forty years of service at Rensselaer Polytechnic Institute, Troy, N. Y. He joined the faculty in 1908 as a professor in electrochemistry and has served as the head of the departments of electrical engineering, physics, and metallurgical engineering. Dr. Hunter was born in Auckland, New Zealand, in 1878, received a B.S. and M.A. degree from Auckland University College and then went on to London for a doctor of science degree from University College. He continued his studies at the University of Gottingen, Germany, at the Sorbonne in Paris, and the Techniche Hochschule at Karlsruhe, and came to the States in 1905 to work in the General Electric research laboratory in Schenectady.

Thomas A. Jackson is engaged as

a metallurgist and representative for the Volcan Mines Co. at Mahr Tunnel, Peru.

Edward C. Keller, formerly plant metallurgist with the Duquesne Smelting Corp. at Pittsburgh, has joined the firm of K. Hettleman and Sons at Baltimore, Md., as assistant manager of the Dixie metals division.

George V. Luerssen, chief metallurgist for the Carpenter Steel Co., was presented with the first annual David Ford McFarland award by the Penn State Chapter of the ASM at a dinner meeting on May 12. This award is made annually to a Penn State metallurgist who is judged to have attained eminence in his profession so as to bring credit upon himself and his alma mater. Mr. Luerssen talked on iron-nickel alloys and emphasized the need for further metallurgical attention in this field.

Robert E. Mahr has resigned his job with Sylvania Electric Products Inc. and is now located with the Chrysler Corp., central engineering division, powdered metals lab. in Highland Park, Mich. He will be glad to hear from any friends at his home at 2360 Bacon Ave., Berkley, Mich., phone number Lincoln 2-8728.

Daniel J. Milevich is mechanical foreman in the open hearth department of the International Harvester Company's Wisconsin Steel Works at S. Chicago, Ill.

Martin S. Miller is research metallurgist in the research laboratory of the Crucible Steel Co. of America at Harrison, N. J.

Herbert E. Pagel is now in Birmingham, Ala., working for the Tennessee Coal, Iron and Railroad Co. as a laboratory assistant in the metallurgical department in the Fairfield sheet mill.

Clarence B. Randall was elected to the presidency of the Inland Steel Co. on April 27 to succeed **Wilfred Sykes,** who becomes chairman of the executive committee. Mr. Randall, who had been assistant to the president, was vice-president in charge of materials. Mr. Sykes advised stockholders that net income for the quarter ended March 31 amounted to $9,254,230 or $1.89 a share, compared with a net of $8,458,544 or $1.73 for the March quarter last year. Mr. Sykes reported that there is now "ample evidence" that the pent-up demand for steel following the war is being satisfied, and that Inland's and the industry's capacity will be more than sufficient to supply the needs of the country, even at maximum peacetime consumption.

L. F. Reinartz has been named assistant vice-president of the Armco Steel Corp. He will continue to manage the Middletown division of Armco and the company's coal mining division in West Virginia will report to him. Mr. Reinartz began his Armco career in 1909 as a chemist in the open hearth department after receiving a metallurgical degree from Carnegie Institute of Technology. He advanced from assistant superintendent to superintendent of the open hearth department at Middletown, to assistant general superintendent to works manager of East works and in 1938 to manager of the Middletown division.

F. W. Bremmer

F. W. Bremmer, for 25 years with the National Supply Co., has been elected vice-president in charge of manufacturing, a post which has been vacant since **Charles R. Barton** retired a year ago. Mr. Bremmer has been works manager of the Spang-Chalfant division's Ambridge plant since May, 1948. He was first employed by the Standard Seamless Tube Co. of Ambridge, Pa., and shortly after that company was acquired by Spang-Chalfant became assistant superintendent of the hot mills. Spang Chalfant was acquired by National Supply in 1930 and ten years later Mr. Bremmer was appointed works manager of the division's Etna, Pa., plant, a post he held until his appointment as works manager of the Ambridge plant last year.

Earl W. Ross, who had been with the Naval Shipyard in Brooklyn, N. Y., has gone to Teterboro, N. J., to work for the Bendix Aviation Corp.

Bruce M. Shields has changed his address from the U. S. Steel Corp. of Delaware, Pittsburgh, to the metallurgy department of the Carnegie-Illinois Steel Corp. South Works, 3426 E. 89th St., Chicago 17.

Eric G. Skarin is service metallurgist for the Ohio Ferro-Alloys Corp., Citizens Bldg., Canton 2, Ohio.

Cyril Stanley Smith, director of the Institute of Metals at the University of Chicago, was one of the principal speakers at the dedication of two new buildings on the campus of Illinois Institute of Technology on June 17. He lectured and led a discussion on the "Microstructure of Metals" at a symposium in the auditorium of the chemistry building, one of the two being dedicated. The other new structure is the metallurgical and chemical engineering building.

F. M. Stearn, formerly with the Appleby Frodingham Steel Co., is now assistant metallurgist in the process development department of Henry Wiggin & Co., Birmingham, England.

Ralph H. Sweetser writes from his new address, RFD 2, Portsmouth, N. H., that he spent four months in Ohio in the midst of the controversy on the "rubber conveyor belt system" from Lorain to East Liverpool, Ohio, for conveying iron ore from the Lake to the Ohio River and coal from the River to the Lake. Mr. Sweetser fails to see how this will help the steel industry and feels that it won't help the railroads. He has found quite an interest in sponge iron, but doesn't know whether it is because of the scarcity and high cost of blowing engines or because of the tests of the Bureau of Mines at Laramie, Wyo.

Elbert C. Troy, who was chief metallurgist for the Dodge Steel Co., is now foundry engineer for the National Engineering Co. He receives mail at 5 E. Broad St., Palmyra, N. J.

J. C. Warner, dean of graduate studies and head of the chemistry department at Carnegie Institute of Technology, has been elected vice-president and a member of the board of directors of the Electrochemical Society.

D. F. Zlatnik is plant superintendent for the Basic Reduction Co. on the hydrometallurgical extraction, recovery, and refining of lead and zinc. His mail goes to P. O. Box 92, Henderson, Nev.

• In Petroleum Circles

John A. Fraher, formerly with the Sinclair Prairie Oil Co., is now employed as a petroleum engineer by the Bureau of Mines, Box 621, Laramie, Wyo. He is working on secondary recovery problems in the Rocky Mountain era.

Earl G. Griffith, after a little over three years with the Mene Grande Oil Co. in the Maracaibo Lake basin, the last year and a half as resident geologist of the Bolivar Coastal fields, de-

cided that it was time to put in a "contract" in the U. S. Moreover he and his wife wanted their son to be born in the States and enjoy the advantages of good medical care. Mr. Griffith arrived home 24 hours prior to his son's birth, which was pretty close timing. At present he is a petroleum geologist with The Texas Co. in the Montana district. He is living in Lewistown, Mont., and thinks it good country, with lots of hunting and fishing.

James W. Hepburn recently received appointment as assistant manager of the vertical turbine pump division of the Worthington Pump and Machinery Corp., Harrison, N. J. Mr. Hepburn set up his headquarters at the Corporation's Denver Works early in May, where he will be responsible for customer relations in the sale of vertical turbine pumps in the territories west of the Mississippi, including Chicago, St. Paul, and New Orleans. Mr. Hepburn was graduated from the engineering school of the University of Utah in 1929 and joined Worthington that same year as a sales engineer. In 1943 he was made district manager of the El Paso office, and since 1945 has been in the reciprocating pump division at the Harrison Works.

Michel J. Pagezy, a French student who had been studying at the Missouri School of Mines, has been in training as a petroleum engineer in production with the Sinclair Wyoming Oil Co. He expected to return to France in July to offer his professional services to the French petroleum industry.

Robert H. Parks has moved to San Antonio, Texas, and represents the Sunray Oil Corp. on the Seeligson Engineering Committee. His address is Transit Tower, San Antonio.

C. Sheldon Sharp has gone to Dhahran, Saudi Arabia, where he will be employed as a geophysicist working with gravity exploration for the Arabian American Oil Co. For the past ten years he had been working for the Brown Geophysical Co. on gravity surveys.

J. H. Sidwell has changed his address from the Union Tank and Supply Co., Tulsa, to the Hiawatha Oil and Gas Co., Milan Bldg., San Antonio, Texas.

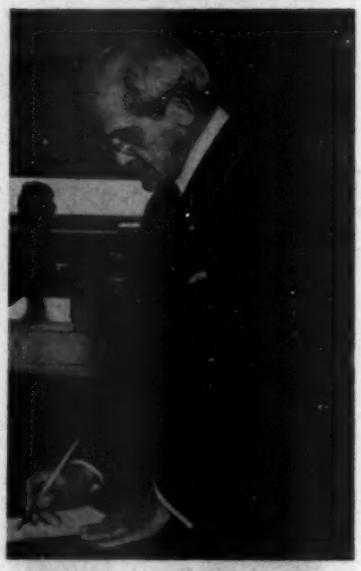
M. H. Stekoll informs us that the main office of the Stekoll Petroleum Co. is now located at 1700 M&W Tower Bldg., Dallas. He has recently moved from Independence, Kan., where the Company, which is engaged in the oil producing business, has several waterflood operations.

Munsey W. Waters, engineer for the George E. Failing Co., manufacturer of rotary drilling equipment, can be reached at 1001 Sunset Drive, Enid, Okla.

Bing Quai Yee is addressed at the exploration department of the Carter Oil Co., P. O. Box 120, Denver, Colo. He had been at Oklahoma University.

Robert W. Zwicky has the job of junior exploitation engineer with the Shell Oil Co. and receives his mail at 2436 Shakespeare, Houston, Texas.

Obituaries



CHASE SALMON OSBORN (Member 1916), former governor of Michigan, prospector, geologist, writer, and a man who helped create some of the history of his times, died in Poulan, Ga., on April 11, at the age of 89.

Mr. Osborn's Lincolnesque, self-made career began in an Indiana log cabin in 1860, and his first job was that of newspaper boy. By 1912 he had bought, published, and sold three mid-western newspapers. A penchant for hunting took him off on expeditions to the Canadian woods, and led to his discovery of the Michipicoten iron range and the Moose Mountain range in that country's northland, which discoveries brought him a considerable fortune. He was instrumental in the development of the Great Lakes region, and did much field work in the Lake Superior districts of Michigan, Wisconsin, Minnesota, and Ontario.

The efforts of "Uncle Chase" were not confined to the United States, however, as witness his discovery of the Kiruna and Luossavara deposits in Lapland, and other iron ranges in Africa, the Orient, and Latin America. His adventures in Madagascar were presented in his book "Madagascar, Land of the Man-Eating Tree," in 1924.

Mr. Osborn held no less than seven university degrees, although he had only that number of years of formal schooling. The degrees were honorary—honoring the man who was Michigan's governor from 1911 to 1913; who wrote one of the nation's first workmen's compensation laws; who was instrumental in drafting Theodore Roosevelt for the presidency; who founded the Michigan Fellowship in Creative Art; who headed the National Committee of Independent Voters for Roosevelt in the 1940 campaign; who knew nine Presidents, and gave away a fortune.

The list of organizations of which he was a member would fill most of this column. As an author, he wrote "The Andean Land"; "The Iron Hunter"; "The Law of Divine Concord"; "A Short History of Michigan"; and other volumes.

Perhaps he left a clue to the secret of his success. Someone once asked him what schools he had graduated from, to which he replied—"Big woods and mountains."

ANDREW MELLICK TWEEDY (Member 1914), mining engineer, and former director and general manager of the South American Development Co., died at San Angelo, Texas, on Jan. 6. He was 64 years old. Mr. Tweedy was a native Texan, but he came East to take his B.S. in mining engineering from the Columbia School of Mines in 1906. He worked for the American Pyrites Co. in Herman, N. Y., for two years, and then the next eight years found him employed in various Mexican mining camps. In 1916, he became resident manager for the South American Development Co. in Portovelo, Ecuador. Thirteen years later he was managing the company from its New York offices, and in 1935 became a director, continuing in that post until his retirement in 1943. His services were retained as a consulting engineer for the firm until the time of his death.

One of his noteworthy achievements was the placing of the old Zaruma operation on a profitable basis, and Mr. Tweedy's ability, vision, and understanding were well known to have played a major part in the solution of the many problems therein presented.

Necrology

Date Elected	*Name*	*Date of Death*
1948	Robert H. Bedford	April 26, 1949
1948	Charles A. Bruce	March 11, 1949
1892	William H. Corbould	March 16, 1949
1948	William J. Flori	May 7, 1949
1896	Robert H. Jeffrey	January 31, 1949
1920	Joseph P. Labaw	April 27, 1949
1909	James E. Little	May 24, 1949
1947	Leonard Lynch	Oct. 18, 1948
1890	James MacNaughton	May 26, 1949
1909	Charles Montel	June 1, 1949
1916	Hubert Merryweather	June 7, 1949
1912	William C. Phalen	May 27, 1949
1945	Russell E. Reilly	Unknown
1917	Chard O. Sanford	January 31, 1949
1945	George L. Smith	Unknown
1918	Philip S. Smith	May 10, 1949
1915	Walter Stalder	May 27, 1949
1938	Arthur B. Yates	May 16, 1949

Proposed for Membership

Total AIME membership on May 31, 1949, was 15,729; in addition 4348 Student Associates were enrolled.

In the following list C/S means change of status: R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate; F, Junior Foreign Affiliate.

ARIZONA

Ajo — NEWETT, JOHN W. (M). Chief engineer, New Cornelia branch, Phelps Dodge Corp.

Globe—MELLUS, HERBERT HEATH. (C/S—J-M). Pit engineer, Inspiration Consolidated Copper Co.

Inspiration—PATE, MANOAH LASLEY. (C/S—J-M). Mining engineer, Inspiration Consolidated Copper Co.

Tucson — KUMKE, CHARLES AUGUST. (R-M). Mining engineer, Bureau of Mines.

ARKANSAS

Smackover — VESTAL, WILLIAM ARTHUR. (C/S—S-J). Petroleum engineer, Phillips Petroleum Co.

CALIFORNIA

Hollywood — OFFEMAN, RICHARD E. (M). Manager, Pacific Coast division laboratory, Baroid Sales Division, National Lead Co.

Los Angeles—HAYTHORNE, PERCY ALLEN. (M). Research engineer, supervisor of metallurgical research, Lockheed Aircraft Corp.

Riverside—NICKERSON, KENNETH WESLEY, JR. (C/S—S-J). Geologist, Kennecott Copper Corp.

Rodeo—MONFORT, JOSE VARGAS. (C/S—J-M). Smelter chemist, American Smelting and Refining Co.

San Carlos—HACK, WALTER LAWRENCE. (M). Chief metallurgist, Western Gold and Platinum Works.

Taft — HENDERSON, ALEXANDER DUNCAN, JR. (R,C/S—JA-M). Field superintendent, Stanolind Oil Co. of California.

COLORADO

Denver — UNDERWOOD, ERVIN EDGAR. (C/S—J-M). Graduate student, MIT.

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Cliffort Ray Hudson.....Okla. A&M
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David William Levinson..Ill. Inst. Tech.
Clifton M. McDaniels..Colo. Sch. Mines
John Flett Rollins.....Univ. N. H.

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History of Pumping at the Chief Consolidated Mine, Eureka, Juab County, Utah

By JOHN G. HALL,* Member AIME

The pumping operations at the Chief mine have been unique in the respect that for many years the entire flow of water into the mine has been disposed of by pumping into natural underground "caverns" or "sinks." Volumes up to 4000 gpm have been pumped into these caverns with no apparent tendency for the caverns to fill with water, and it has never been proven that any of the water returns to the mine workings.

Major pumping operations have been carried on during two periods, the first from 1918 to 1927, and the second from 1942 to the present time.

Early Pumping Operations

CHIEF MINE

The Chief Consolidated Mining Co. was organized in 1909, and for the following nine years ore was developed and mined from the 600 level down to the 1800 level, all above the permanent water table, the 1820 level. The ore occurs as extremely-irregular pipes of replacement ore in limestone, and to date a total of approximately 2½ million tons of ore has been produced. The ore was highly oxidized down to the permanent water level, and some highly-oxidized ore runs occur beneath the permanent water table.

In 1916, with extensive mining being done on the 1800 level, 20 ft above the water table, there were indications that a zone of secondary enrichment might exist below the water, and in order to follow the ore runs to greater depth, it was realized that arrangements would have to be made to pump water to the surface.

The original pumping installation was designed to pump 350 gpm in five stages against a 1900-ft head to the surface. By January 1919, the water had been lowered to the 1900 level and an excellent grade of silver-lead ore was being produced from the zone of secondary enrichment. At this point, the flow of water equalled the capacity of the pumps, and pumps of an additional 1000 gpm were installed to supplement the original system. By January 1920, the water had been lowered approximately 100 ft, and the total flow of water was 1000 gpm. The water was being pumped from many different places in the mine where ore was being followed downward, with 27 different pumps operating below the 1800 level, mainly Cameron air-driven sinker pumps. These first sinking pumps were cumbersome and inefficient, and each of the larger pumps weighed approximately three tons and required tremendous volumes of compressed air.

During this period, an exploration drift being extended north and west from the Chief shaft on the 1600 level encountered a large natural cavern some 2000 ft from the shaft. This cavern in places measured 60 ft in diameter. Sometime later the disposing of water into this cavern was suggested, and as an experiment to determine the results of such an operation, an attempt was made to fill the cavern by pumping in a small volume of water, but the water disappeared as fast as it was discharged into the cavern. It was decided then to try the cavern as a drainage outlet for the entire volume of water being pumped to the surface, and the water apparently did not return to the mine workings. Subsequently water up to 3000 gpm was pumped into this cavern. An attempt was made to determine whether any water was being returned from the cavern to the lower workings, and 100 lb of sodium fluorescein salt was added to the water discharged into the cavern, but no trace of it was found in the drainage water in the mine. Results of another such test will be described later.

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TP 2613 A. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Aug. 30, 1949. Manuscript received Jan. 10, 1949.

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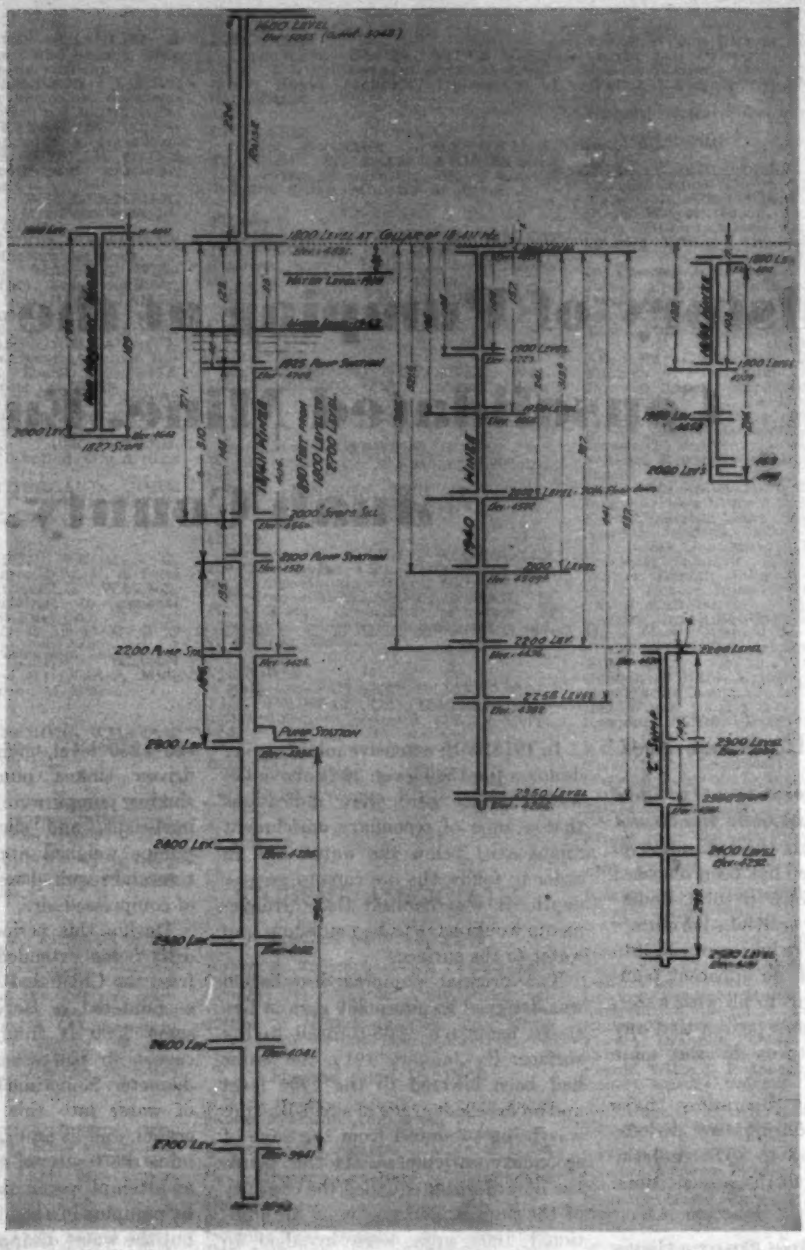

FIG 1—Generalized section of main winzes operating below the water level at the Chief Consolidated No. 1 mine.

By 1921, ore had been followed down to the 2000 level and two single-compartment vertical winzes had been sunk to the 1900 level (18-88 and 1800 winzes), and about this time another single-compartment shaft was raised from the 1900 level to the 1800 level. This is now known as 1940 winze. Fig 1 shows a generalized section of the main winzes.

With the success thus far encountered by discharging the water into the 1600 cavern, it was decided to attempt to dispose of the water pumped from 1940 winze somewhere on the 1800 level to eliminate the 200-ft lift to the 1600 cavern. With this in mind, a pipeline was run some 2000 ft to the bottom of the Chief No. 2 shaft on the 1800 level. It was hoped that this area would contain a crack or opening that would absorb the water pumped into it. However, the ground in this area proved to be very impervious, and the experiment met with no success. Later, a natural cave was encountered 1000 ft north of 1940 winze and an attempt was made to pump into this. A cement bulkhead was constructed across the drift several hundred feet from the cave and water was pumped into it. A pressure gauge was installed in the bulkhead and within 12 hr the pressure behind the bulkhead had built up to 175 lb. This attempt to dispose of the water was abandoned.

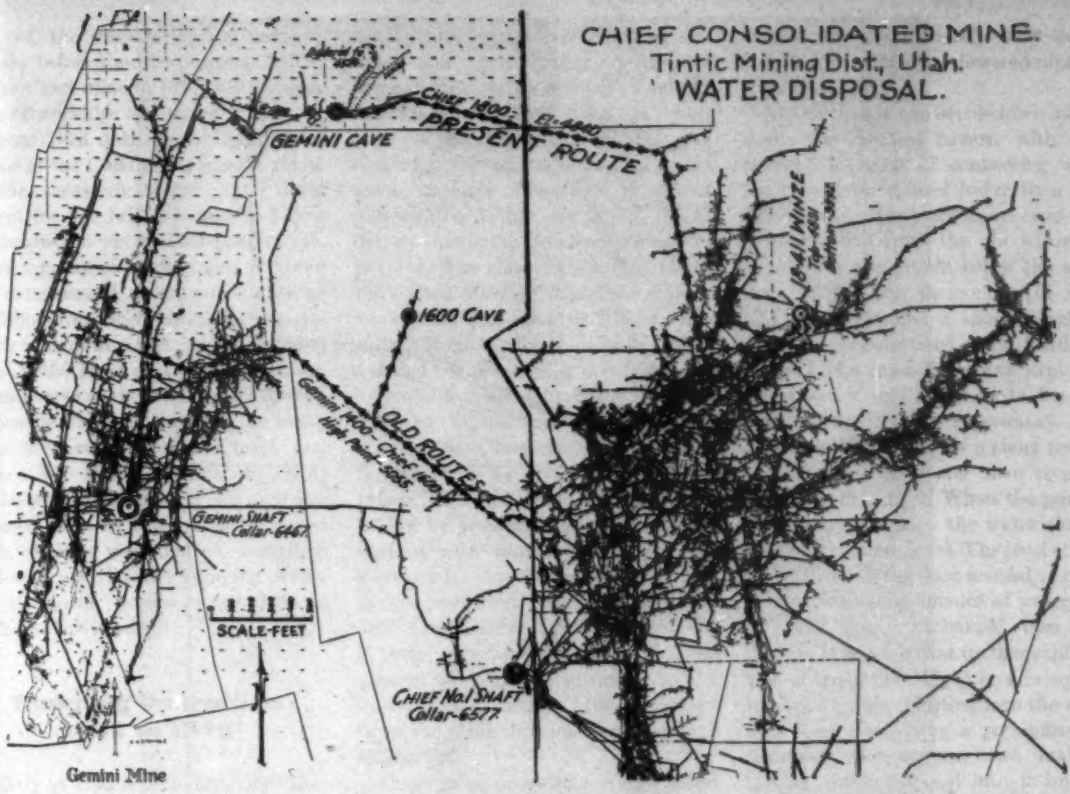

FIG 2—Composite plan map of Chief No. 1 mine and Gemini mine showing the locations of 18–411 winze, the 1600 cavern and the Gemini cavern. Also shown are the old and present routes to the caverns.

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By 1924, it was felt that the underwater ore bodies were large and continuous enough to warrant sinking a three-compartment vertical shaft in limestone from the 1800 level to the 2200 level to facilitate mining and pumping operations. This shaft is now known as "18-411 winze." When this winze was completed to the 2200 level, a new and much more efficient pumping system was installed to replace the old system that had been built up gradually over a 6 year period to cope with changing conditions as workings were extended ever deeper and the volume of water increased. A raise was driven from the 1800 level, at 18-411 winze, to connect to the 1600 level to accommodate the pump lines. The water was then piped from this point directly to the 1600 cavern some 1900 ft westerly of 18-411. The newly-installed pumping system was so designed that all the water from the mine could be collected in a sump on the 2200 level, and from this point was pumped in three lifts by series-connected centrifugal pumps directly to the 1600 cavern. This system had a capacity of 1700 gpm, with a standby system of the same capacity. Fig 2 is a plan of the water disposal system.

From 1924 to 1927, workings in the 1940 area were extended to the 2350 level and another subshaft known as "C" sump was sunk on or near ore from the 2200 level to the 2500 level which was the deepest level reached.

In March of 1927, a combination of unexpectedly adverse conditions occurred which affected the profitable operation of the Chief mine. Foremost of these was the drop in metal prices. To meet these adverse conditions, it was deemed expedient to give up the lower workings, and the pumping expense that was involved in their operation. It was planned to attempt to follow additional ore runs down to the water level to help pay the expense of any future pumping operations.

When pump operations were stopped, the pumps, all electrical equipment, and mining tools were removed from the lower levels, but all pipe and track was left intact. The lowest levels flooded rapidly, and the water rose from the 2500 level to the 2200 level in about 24 hr, from the 2200 to the 2100 in two days, and from the 2100 to the 2000 level in about three weeks. From this point the water rose very slowly and 24 months later the water was at the 1950 level. Twelve years later, in 1942, the water was still only up to the 1860 level or 40 ft below the original level, although it was rising gradually still.

Developments at the Chief mine from 1918 to 1927 had carried operations 700 ft below the natural water table. Beginning with a few gallons, requirements increased to a maximum of 2000 gpm when operations ceased.

An interesting sidelight concerning the 1600 water cavern is the fact that when pumping was halted in 1927 it was found that a considerable accumulation of slime material had settled out of the pump water in the drift approaching the 1600 cavern. Assays were made upon this material and as a result some 480 tons of ore averaging $7.65, at 1928 prices, was retrieved. This material had been carried in the drainage water during the period of pumping.

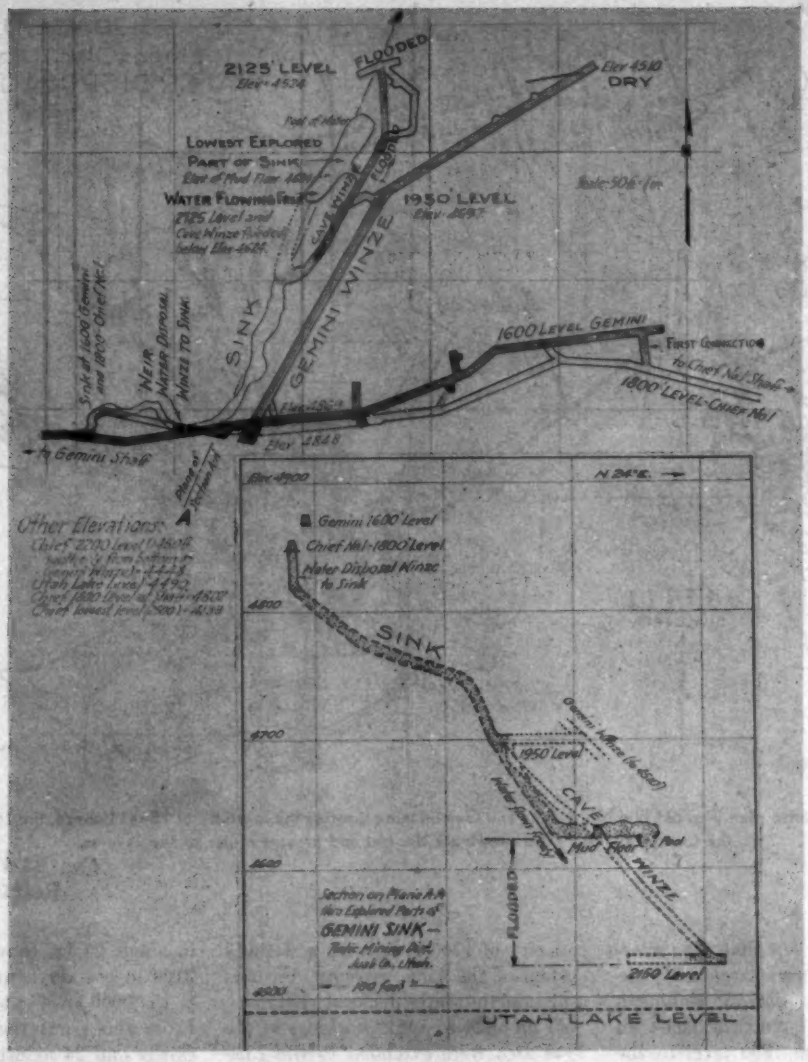

FIG 3—Plan map and section showing details of workings in and near the Gemini cavern, Chief Consolidated mine.

GEMINI MINE

During the period 1918 to 1925, pumping operations were also carried on at the Chief Consolidated Mining Company's Gemini mine. An exploration drift on the Gemini 1600 level, which approximately equals the Chief 1800 level, also encountered a natural cavern, or sink, some 1100 ft northwesterly from the Chief 1600 cavern. With the success of the Chief 1600 cavern it was decided to pump the Gemini water into the Gemini cavern rather than to the surface, and this operation also met with success. The total flow pumped into this cavern at that time was only 300 to 400 gpm, although this cavern now assumes an important role in Chief pumping.

The Gemini cavern is some 1600 ft northwest of the 18-411 winze in the Chief mine, and when pumping was halted at the Gemini in 1925, it was decided to attempt to explore and survey its downward extensions. It was hoped that it might be possible to follow the cavern downward to an elevation lower than the water level in the Chief, and then to drive a drift from the Chief to connect with the cavern, and thereby greatly reduce the head requirements of the pumping system. Two men first descended into the cavern on ropes, and were successful in exploring the flat-lying cavern some 200 ft of vertical elevation below the Gemini 1600 level or approximately 160 ft below the natural water table. At this point a large room with several feet of mud on its floor was encountered. No opening large enough to allow the men to descend farther could be found leading out of this room. It was then decided that in order to further explore the cavern it would be necessary to sink a small incline winze near the cavern, and to keep contact with the cavern by drifting to it at various elevations. The winze was extended to the elevation of the mud floor and some 100 ft below, but no large openings were found below this point, although the limestone was extremely vuggy and porous. Explora-

tion of the cavern was abandoned shortly before the pumping was halted in the Chief mine in 1927. Fig 3 shows plan of workings at Gemini cavern.

From 1928 until 1942 mining operations at the Chief mines were confined to the areas above the water level except for one brief attempt to follow ore below the water. This was in 1941, when a group of block leasers followed the extension of an ore run known as "Millionaires' Row" down to the water level, which was still below the 1900 level (1950 level at 18-27 winze). An attempt was made to follow this ore run below the water by pumping the water from this area to the 1800 level, and thence into 18-411 winze some 900 ft to the west. The water in this area was lowered 50 ft by the lessees; however, with obvious recirculation occurring, and with very limited pumping capacity, it became necessary for them to abandon this attempt.

Pumping Operations 1942 to 1946

Early in 1942 it was announced that because of the critical shortage of lead and zinc, the government would allot to mining companies an increased price for lead and zinc based on a tonnage quota to be determined from 1941 production. Any metals produced over and above this quota would be paid for at the advanced price. It was known that the underwater areas of the Chief mine contained large unmined tonnages of these products developed during the period 1918 to 1927. During this early period of mining, the zinc contained in the ores brought penalties from the ore buyers, and therefore mining was done as selectively as possible, and ore with high zinc content was left unmined. Also, metal prices were low and mechanical mining equipment was practically lacking in 1927 when pumping had been stopped.

It would now be possible, by shipping these lead-zinc ores to custom flotation mills, to mine the ore runs on a large tonnage basis by replacing the expensive square-setting methods by cheaper open-stoping and shrinkage methods. Also the use of modern mechanical mining equipment would further decrease the mining costs from the 1918 to 1927 level. It was therefore decided to unwater the lower levels of the Chief mine.

The original scheme was to unwater through 18-411 winze to the 2200 level, the bottom level of the shaft at this time, and then further to unwater through "C" sump subshaft from the 2200 level to the 2500 level, the lowest level of the mine. The difficulty of obtaining the proper pumping equipment, because of wartime scarcities, necessitated using equipment immediately available to best serve the purpose. The close cooperation of the Park-Utah Mining Co. and the diligent work of the late Leonard Wilson, Consulting Engineer for the Chief, greatly speeded the unwatering operation.

It was decided to discharge the water into the Gemini cavern, rather than into the 1600 Chief cavern, by pumping the water to the 1600 Chief level, as before. This time the water was allowed to flow by gravity through a drift connecting with the Gemini mine, and thence with the Gemini cavern. This cavern was used rather than the old 1600 Chief cavern, for it was felt that if there were any possibility of some portion of the water returning to the mine, that a cavern 1100 ft farther from the mine workings would return less water.

Unwatering operations were started in August 1942. Deep-well and horizontal centrifugal pumps with a capacity for discharging 2400 gpm to the Gemini cavern were installed at the 1800 level collar of 18-411 winze. The water was lowered to the old 1925 pump station level with these pumps. The next step was to lower a 350 hp, 3000 gpm Byron-Jackson submersible-type pump down 18-411 winze from the 1925 level to the 2150 level, and to install a booster pump on the 1925 level. With this system the water was lowered to the 2150 level. In the installation of this pump, which was lowered on its column beneath the water in 18-411 winze, it was found that the shaft was completely blocked at about the 2150 level. Therefore, it was necessary to further unwater through 1940 shaft.

In May 1944, with the water standing at the 2150 level, a project was completed that would simplify, expedite, and lower the cost of unwatering the lower levels of the Chief, and for all time reduce pumping costs at the Chief. A drift was connected on the Chief 1800 level directly with the Gemini cavern so that the pumped water could be discharged into the cavern without the necessity of lifting it 215 ft higher to the 1600 level. With the pumps operating at this reduced head, the volume pumped was increased to approximately 4000 gdm, and the water level was lowered rapidly after this date.

At this time it was decided to explore again the Gemini cavern with the thought in mind of connecting with the cavern on a level lower than the 1800 level. The intention was to diamond drill from the old winze to explore for the cavern below the mud floor. When the diamond drill hole had been extended a short distance, water was encountered and the drilling halted. The mud floor was explored again and it was found to be flooded with water. As an experiment, the pumps were shut off for a short period of time, and the water then receded from this mud floor. When the pumps were started again, the water slowly rose to its former level. The level of the water flooding the floor seemed to have no relation to the amount of water, up to 4000 gpm, discharged into the cavern. It was felt that further exploration of the cavern might be unwise, for it would require blasting into the mud floor, and there was a possibility of damming the cavern, and making further water disposal into it impossible. Exploration of the cavern was abandoned again.

During this time, by the use of two 350 hp submersible pumps which were lowered from the 2100 level of 1940 winze to the 2300 level, the mine was unwatered to the 2300 level. The water was piped from 1940 winze along the 2100 level to 18-411 winze where booster pumps lifted the water directly to the cavern. Upon reaching the 2200 level, of 18-411, through 1940 winze, it was found that broken rock had accumulated on the 18-411 winze 2200 station and that this had been the obstruction encountered in lowering the original submersible pump in 18-411 winze. It was also found that the collar of "C" sump subshaft, and the stope above had caved. It was therefore decided to extend 18-411 winze to the 2300 level and to connect to "C" sump on this level and to unwater to the 2500 level from this point. Sinking was completed late in 1945, and the two 350 hp submersible pumps were removed from 1940 shaft and installed in 18-411 winze with the pump intake below the 2300 level in the shaft sump. These pumps were series-connected to booster pumps on the 2100 level. This again established 18-411 shaft as the main pumping area. Early in 1946 the 2300 level was connected to "C" sump, and a 125 hp

submersible pump installed there to unwater to the 2500 level. This completed the unwatering to the lowest level of the Chief mine.

During 1947, 18-411 winze was extended to the 2735 level and stations cut on the 2400, 2500, 2600, and 2700 levels, the present bottom of the mine.

Present Pumping System

The present pumping system consists of two separate sets of pumps each with a capacity of 3000 gpm at 950 ft head. These discharge to the Gemini cavern on the 1800 level. Both sets of pumps are automatically controlled from a central control panel on the 2300 level. The automatic features control the water level in the sumps, start pumps after power failures, and change pump systems in the event of failure of the operating system.

The No. 1 System consists of a 350 hp submersible unit in the shaft sump on the 2700 level which pumps to a sump on the 2300 level. A 500 hp centrifugal station pump, primed by a 40 hp deepwell pump, lifts the water from this point directly to the Gemini cavern on the 1800 level. This system has a capacity of 3000 gpm. The 500 hp pump is operated by a variable-speed motor, the speed of which is automatically controlled by a liquid rheostat to maintain a constant water level in the 2300 sump.

The standby system consists of a 350 hp submersible unit on the 2700 level, a 350 hp submersible unit in the 2300 sump, series-connected to a variable speed 300 hp booster pump on the 2100 level, which pump directly to the Gemini cavern. The speed of the 2100-level booster pump is controlled by a float switch in the 2300 sump which in turn controls a system of resistors on the 2100 level. This system also has a capacity of 3000 gpm.

During the period from 1942 until 1948 the Chief mine was unwatered from the 1860 level to the 2500 level, and new developments carried the workings an additional 235 ft downward to the 2735 ft level, 915 ft below the original water table. During this period, approximately 500,000 tons of lead-zinc ores were produced. Upon unwatering, the mine was found to be in excellent condition; timbers, pipelines and track were well preserved and in usable condition. In many areas, an accumulation of slimes or mud up to 3 ft in depth had deposited in the drifts. These slimes were found to contain enough lead and zinc to warrant shipping them as ore.

The total flow of water into the mine is now 2600 gpm, which amounts to about 50 tons of water pumped to each ton of ore extracted. The seasons have no apparent effect on the quantity of water entering the mine. The amount of water developed is not proportional to the depth sunk, but is more nearly proportional to the distance opened laterally on the lower levels. Local structures affect both the level and the quantity of water encountered, but the general effect of the pumping is to completely unwater a very flat (4° from horizontal) funnel-shaped area radiating from the pumping point. When the water was lowered 700 ft in the Chief mine, records show that the water was lowered 200 ft in the Grand Central mine, approximately one mile to the south. Little more is known about the effects of the pumping on other nearby areas, as surrounding mines are not developed below the original water table.

The use of submersible-type pumps has greatly reduced the hazards of flooding due to sudden inrushes of water, to prolonged power interruptions, or to other unforseen conditions which might cause pump operations to cease for short periods of time. At the present time, the mine could flood from the 2700 level to the 2300 level without damage to the pumping system. This gives a leeway of several days in which the pumps could cease to operate before flooding, an interesting comparison to the system used in 1927, when the lowest pumps flooded a very few minutes after stopping.

Water Recirculation Test

In December 1948, a test for recirculation of water from the Gemini cavern to the Chief mine was made by the use of sodium fluorescein salt which stands at the top of the list of chemicals and dyes used for tracing underground waters. Fluorescein has a reddish-orange color, but when dissolved in water and diluted, appears a brilliant green. Under ultraviolet light, the water solution fluoresces a brilliant green. One part of fluorescein in 40 million parts of water is visible to the naked eye, one part in 400 million parts of water is easily detected under the ultraviolet light, and with special care, one part in 10 billion parts of water can be detected by the aid of a long glass tube. Eight kilograms of fluorescein salt were added to the water discharged into the cavern, and water samples taken at regular intervals at various points in the mine over a period of several months. No trace of the fluorescein was found in the mine water. The 8 kg of fluorescein added to the discharge water at the cavern is enough to pollute the total amount of water pumped in approximately nine months. Numerous tests were made to determine if contact with any known minerals or rocks in the Tintic District would weaken or destroy the fluorescein color, and nothing was found that would affect the color determinations. It is felt that this test substantiates the belief that water discharged into the Gemini cavern on the Chief 1800 level does not return to the mine.

Theory of the Caverns

There have been many theories offered to explain the disappearance of the water discharged into the Gemini cavern. One theory is that the area being unwatered is a perched water table, and that the cavern is a sealed pipe that extends below this perched water table. This is comparable to pumping from one tank to another some distance below. The water cannot return to the upper tank. The fact remains however, that the mystery of the cavern is yet to be solved.

The use of this cavern 1800 feet below the surface for the disposal of the entire flow of water into the workings of the Chief mine has effected tremendous savings in investments in pumping equipment and costs by reducing the static head requirements of the pumping system from 2735 ft, required to pump to the surface, to 935 ft, to discharge to the cavern. Without this cavern the economical operation of the underwater areas of the Chief would be a question.

Acknowledgment

Appreciation is expressed for helpful information received from previous reports written by the late Walter Fitch, Sr., Cecil Fitch, Sr., H. J. Pitts, and J. Fred Johnson, past and present officers of the company, also to information given by Sam Colovich who worked on the original 350 gpm system installed in 1918, and who is still in charge of the pumps at the mine.

Sublevel Stoping in Small Mines

By J. J. LILLIE,* Member AIME

Sublevel stoping was first developed in the Michigan iron mines many years ago. Since that time this method, and modifications with long hole drilling, have been used in a number of nonferrous mines and have been described in various papers and articles. With a few exceptions, the operations where sublevel methods have been applied are producers of large daily tonnages from ore bodies of considerable size. In selecting mining methods for small properties or relatively small detached ore bodies, sublevel methods often have been overlooked.

The method has been used successfully in relatively small operations at Copper Canyon, Nevada, and, more recently, in mining small ore bodies at Darwin, Calif. As a result of this experience, we believe that a review of the general procedure, the advantages noted, and the results obtained will be of interest to many operators of relatively small mines.

General Description

Briefly, sublevel stoping consists of, first, driving sublevel drifts at predetermined vertical intervals through the length of the stope block; second, breaking an initial mining slot across the stope; third, driving crosscut benches from each sublevel by slabbing into the slot; and, fourth, breaking the ground between benches.

Applicability

Since this is an open stope method, it requires wall rock that will stand over reasonable stope lengths without caving or excessive slabbing. Ore must be moderately firm but need not be hard.

The method is best adapted to steep dipping, tabular or lenticular ore bodies but may be applied to ore bodies of almost any shape if their vertical extent is appreciable. It can be used with dips that are too flat for successful shrinkage stopes and can be modified for use with slushers on dips below about 40°.

Initial mining at the Copper Canyon operation consisted of sublevel stopes for the wider ore sections and shrinkage stopes for the narrow sections where ore widths averaged about 15 ft. After some experience and a study of comparative results on completed stope blocks, sublevels were substituted for shrinkage stopes even in the narrow ore widths.

Practical stope lengths depend upon the character of the walls and the continuity of values within the ore body. Where blocks of low grade or waste are included in the stoping limits, these areas can readily be left as pillars for intermediate wall support and longer stope lengths may be planned. Raises can be spotted in narrow or low grade areas and stope lengths adjusted accordingly.

Stoping Details

To illustrate stoping details, assume that we have an ore shoot 15 to 30 ft wide and about 200 ft long, with walls that would stand over a stope length of 80 to 90 ft (Fig 1).

PRELIMINARY DEVELOPMENT

Preliminary development for sublevel stoping would be simple. A service raise is driven at about the center of the block and stope limits planned to leave a pillar around this raise. Sublevel drifts driven each way from this central raise will outline the

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TP 2610 A. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Aug. 30, 1949. Manuscript received Dec. 6, 1948.

* International Smelting and Refining Co., Salt Lake City, Utah.

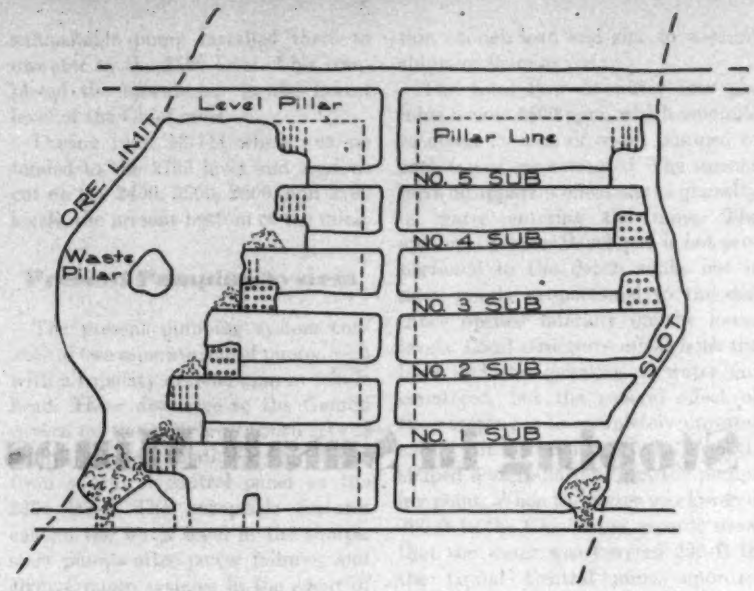

FIG 1—Sublevel stopes: longitudinal section showing general layout and stoping sequence.

end limits of the ore shoot at various elevations. Stoping will start from the ends of the sublevels and retreat toward the central pillar.

HAULAGE LEVEL DEVELOPMENT

On the haulage level, draw points are laid out so that all of the ore can be pulled when broken. The type of chute or draw point selected determines the elevation of the first or lowest sublevel.

At Copper Canyon our first stope layouts used grizzlies over timbered chutes with one or two finger raises feeding each grizzly. After some experimenting we found that the least expensive and generally most satisfactory draw point consisted of a crosscut driven at about a right angle from the haulage drift with a finger raise from the crosscut face.

Ore from the stope piles up on the floor of the crosscut and is picked up with a mucking machine. The length of the crosscut should be planned to allow the mucking machine at least 5 ft of travel between the main line track and the toe of the muck pile. The crosscut track is independent of the main line and the mucker dumps into the side of the cars as the train is pulled past the crosscut. The mucking machine is moved to other points by using a turnsheet on the main line tracks. This side loading eliminates switching and uncoupling of cars and proved faster and more satisfactory than a similar layout with a switch into the crosscut. Oversize boulders are rolled to one side and broken by the mucking machine operator between trips by the train (Fig 2).

Installation, operating and maintenance costs are low with this type of draw point. It has the further advantage, of particular importance in small ore bodies, of reducing to a minimum the amount of ore tied up in a pillar between the haulage level and the bottom of the stope and makes subsequent recovery of this pillar simple.

With any type of draw point, only those at the end of the block where stoping starts need be completed before full production is possible. The rest of the draw points may be prepared as stoping progresses.

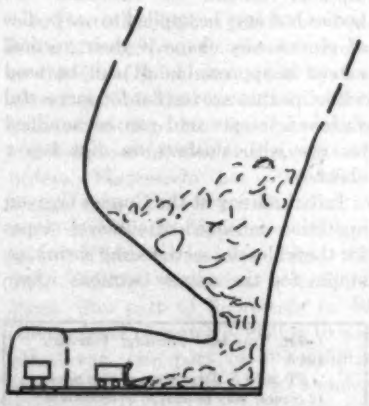

FIG 2—Cross section of mucking machine draw point.

Above the haulage level, the finger raises are belled out until connected to form an undercut, which is mined to the first sublevel. The elevation of this lowest sublevel should be planned so that it can be reached with one or two stope rounds drilled from the muck pile over the fingers. The undercut stope need be taken out only fast enough to provide easy pulling of broken ore from above.

SUBLEVELS

Sublevels above the first one are driven from the raise at vertical intervals of about 23 ft. Our first sublevels at Copper Canyon were driven with a large cross section to help produce initial mill ore tonnage. Best overall results were obtained later with small drifts driven on a 5 to 8 pct grade. Drift rounds were drilled with stopers, thus reducing the number of types of machines and steel in service. Mucking was done with slushers, scraping to the service raise chute.

STOPING

Stoping is started at the end of the block opposite the service raise by excavating a slot across the stope over the first finger raises and extending upward to the top sublevel. At first our mining slots were narrow, transverse shrinkage stopes with access from the sublevels. As we gained experience, the slots were started by driving a series of short raises to connect the ends of the sublevels. Since each lift takes only two or three rounds, driving is fast and inexpensive. This raise is then enlarged by benching from the sublevels until a slot from wall to wall is excavated. The enlarged tops of the first fingers form the bottom of this slot.

At each sublevel, benches, or three-sided crosscuts, are driven to both walls by slabbing into the open slot. Benches are usually driven 10 to 12 ft wide and 9 or 10 ft high. The overhang between the top of one bench and the bottom of the bench above is broken by drilling 9 ft holes from below. Vertical spacing of sublevels to permit this procedure eliminates mucking off benches for down holes and allows all stope drilling to be done with one type of drill.

As the benches retreat from the slot we found some advantages in keeping a curved bench rather than a straight one, with the greatest retreat near the center of the stope. These curved benches are more stable and wall support near the active mining areas is better. More confidence in safety is also created since the miner can readily see the condition of the face below his bench (Fig 3).

Blasting from the top sublevel bench was completed first and thereafter each sublevel bench was kept at least one step ahead of the bench below. This sequence is the reverse of more common sublevel practice but sacrifices none of the advantages of the method and adds considerably to safety. Working benches have better structural support and men do not work on overhanging ground. As viewed from the higher benches, the appearance of the stope, with its stepped-back benches, gives the miner confidence in the ground on which he works; a definite advantage with inexperienced underground crews. Some of the broken ore collects on benches but need not be shoveled as this muck pile is dropped into the open stope with the next blast from below.

Fragmentation in breaking the bench and overhang can be closely controlled by hole spacing and blasting practice. Where limitations imposed by haulage, hoisting, or crushing equipment demand close grizzly spacing, this factor is important. In such situations the advantages of low cost primary breakage that produces a high percentage of oversize may be completely offset by excessive secondary breaking costs.

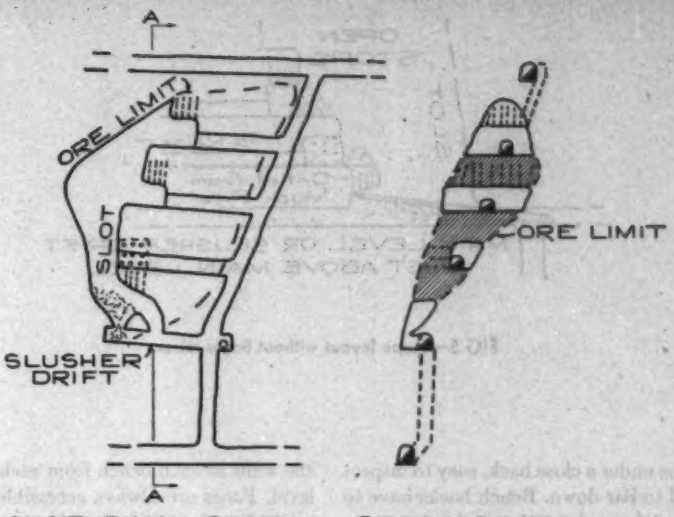

FIG 4—Layout for isolated lens.

Modifications

It is evident from our experience that numerous modifications in general layouts and operating detail will suggest themselves when local conditions are studied in connection with the possibility of sublevel stoping.

Smaller ore bodies may be mined with a service raise at one end, either in ore or just outside the ore limits (Fig 4).

If the ore body bottoms above the haulage level, a slusher drift can be driven just below the ore with finger raises as required. Ore is scraped to a chute at the service raise. This same general layout can be used whenever it is desirable to concentrate loading at one point on the haulage level.

When higher production from an area is desirable, the mining slot can be located in the middle of a block and stopes retreat both ways from this common slot.

In some cases, especially in smaller ore bodies, finger raises may be eliminated and the stope opened directly from the level. Broken ore is slushed to chutes or loading ramps located outside of the stope limits (Fig 5).

The sublevel interval may be varied according to local conditions. In one instance at Copper Canyon, while mining a level pillar along with the stope from below, we broke a 30 ft interval by first taking a normal bench on the top sublevel, then blasting a 5 or 6 ft round out of the back. The remaining ground to the level above was then broken with holes drilled from the muck pile. A larger interval between sublevels with such two stage blasting of the overhang may be advantageous in some cases.

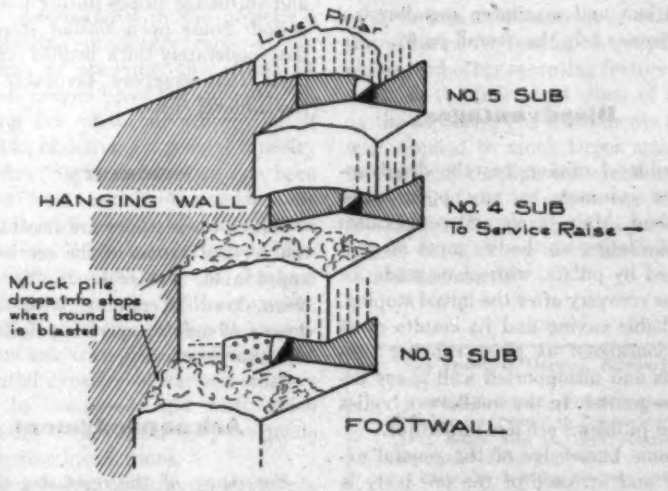

FIG 3—Diagrammatic view of part of stope face looking from left side of Fig 1.

Summary of Advantages

The advantages of sublevel stoping can be summarized about as follows:

Safety factor is high. All work is

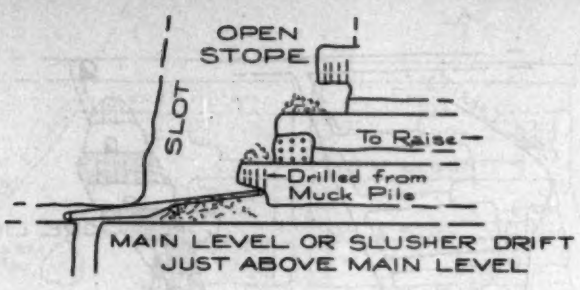

FIG 5—Stope layout without finger raises.

done under a close back, easy to inspect and to bar down. Bench backs have to stand for a short time only. Access to working places is direct and is always along established travelways. Ventilation is good. Safety ropes or guard rails should be used when men are working near the open side of benches.

The direct and easy access to working places for men, supplies and equipment results in a minimum of lost working time.

Drilling can be done simultaneously on several benches and relatively large tonnages can be broken and pulled from small stope blocks.

Supervision and supply service are simple and direct.

All stope drilling consists of slab rounds breaking to a free face, using stoper drills. This type of round can be drilled satisfactorily by relatively unskilled miners and gives low explosives cost with close control of primary fragmentation.

The ore is blasted into an empty open stope so that gravity, to some extent, helps the fragmentation. Broken ore rolls down the footwall so that the method may be used when dips are flat enough to cause considerable difficulty in drawing shrinkage stopes. In shrinkage stopes many ores chimney or hang up on the footwall even with steep dips.

Ore is pulled as fast as it is broken. There is no build up of broken ore inventories that tie up working capital. This also eliminates post breakage oxidation of sulphide milling ore with its frequently adverse effect on mill recoveries. The method does, however, provide for underground storage and continuous stoping during periods when hoisting is interrupted or during milling plant shutdowns.

In deposits with irregular or assay walls there is opportunity to check the walls at each bench from each sublevel. Faces are always accessible and easily sampled. Variations in ore width are readily noted and mining widths can be adjusted during stoping. There is assurance that any ore making out in the walls will not be overlooked and such ore can be mined without difficulty. Waste or low grade areas can be recognized and left on the walls or as pillars.

Full scale production is possible shortly after the block is opened up. Work on haulage levels and draw points can be carried on concurrently with production after the first draw points in the slot area are ready for use.

A moderate amount of slabbing from the walls is not serious since the stope benches retreat rapidly and such slabbing will occur usually over abandoned draw points.

These factors combine to give high tonnages per man shift with low supply, service, and supervisory costs. Clean mining, high underground extraction, and maximum metallurgical recoveries help the overall profit.

Disadvantages

Sublevel mining has the disadvantages common to any open stope method. Main levels and some raises in the larger ore bodies must be protected by pillars, with plans made for pillar recovery after the initial stoping. Probable caving and its results must be considered as pillar robbing proceeds and unsupported wall spans become greater. In the smaller ore bodies these problems are less important.

Some knowledge of the general extent and attitude of the ore body is desirable in planning the mining layout. Development raises and intermediate levels driven while prospecting can usually be fitted into the final plans.

The tonnage from the sublevel drifts is extracted at a relatively high cost. However, even with narrow ore widths this high cost applies to only a small percentage of the total stope tonnage.

Irregular breakage on the benches may leave some ore that is difficult to reach with standard equipment. We found that two or three sets of jointed rods for holes up to 25 ft would take care of these situations without difficulty.

Examples

At Copper Canyon the ore body was continuous over a considerable length, varied from 15 to 80 ft in width with a dip of about 70°. Individual stopes were about 150 ft high and up to about 100 ft in length. Over a period of 20 months the average tons broken per machine shift in sublevel stopes was 105 and average per man shift was 42.7 tons. Pounds of powder per ton broken was 0.74.

At Darwin small ore bodies of widely different shapes have been successfully mined with sublevel stopes. One ore body had a pitch of about 40° and a vertical extent of 90 ft. The cross section was a rough triangle with base and altitude about 100 ft. A slusher layout was used to clean up along the flat footwall trough. Another ore body was a nearly vertical lense, 60 ft long, 80 ft high, and from 10 to 30 ft wide.

Direct costs on these stopes were, respectively, $0.50 and $0.76 per ton lower than the average of other open and shrinkage stopes during the same period. Some open slusher stopes on flat, moderately thick bedded ore gave costs that compare favorably with the sublevel costs.

Summary

Where open stopes are feasible and the vertical extent of the ore body is appreciable, sublevel stoping gives clean, low cost mining, with a high degree of safety, operating flexibility, and assay control.

Acknowledgment

For many of the operating details and data discussed here the writer is indebted to Mr. L. E. Snow, Mr. S. K. Droubay, and their operating staffs.

Jaw Crusher Capacities (Blake Type)

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Published tables of jaw crusher capacities are compiled for the most part from field performance data, interspersed with interpolations, extrapolations, various safety factors, and other modifications. Such a table attempts to balance and equalize field data from widely different materials, with differences of crushability, efficiency of feeding, sizing of the feed, and so on.

The tests described in this paper were undertaken with the objectives of checking previously reported capacities; of studying the effects of various factors upon the capacity, including jaw plate curvature; and, if possible, of deriving a general capacity equation. Such an equation has been derived from the data obtained in these tests. It is given together with factors for its use. While more accuracy than is usually required may be obtained by careful application of the equation, it is of simple form and provides a convenient reference plane upon which the potential capacity of various crushers may be compared, and with which operating adjustments may be made on existing installations.

The principal deviation in these tests from the usual approach consists of a laboratory technique which has been developed for the production of selected capacity data. Recording instruments are connected to crushers in such a manner that a continuous record is produced which discloses the inherent maximum capacity of the crusher and shows capacity decreases caused by hangups. The capacity effects of various crushing conditions are made more evident by this arrangement.

The recording instruments were first applied to a standard sized 10 by 7 in. Blake-type jaw crusher in the laboratory. Sufficient tests were run on this with various combinations of setting, throw, speed, feed sizing, shapes of jaw plates, and other operating features, to establish the individual effect of each on the capacity. The instruments later were applied to much larger crushers in the field, through the excellent cooperation of the managements in the Mesabi Iron Range, and data were obtained which closely corroborated the established trends.

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The capacity equation resulting from the test work is made up of a series of factors, each representing the contributing effects of setting, speed, width of chamber, nip angle, feed density, type of jaw plates, stroke, and the overall operating technique. Fortunately, most of these factors were revealed to be in direct proportion to the capacity for straight plate chambers. This equation is also applicable to chambers using curved plates, with slight modifications resulting from the capacity limitation of the upper portion of the crushing chamber.

The equation has been derived from tests covering a very wide range of feed density and hardness. It has been found valid, providing that the feed material is either nonpacking in character, as is usual, or allowance in designing the crushing chamber shape has been made to accommodate this characteristic.

Preliminary investigation has shown that the equation is also applicable to single-toggle jaw crushers. Conditions of this are that the top of the flywheel rotate towards the top of the crusher opening, and that the horizontal motion of the swing jaw relative to the stationary jaw at the discharge opening be considered as the stroke. The relatively large upper chamber jaw motion would probably result in realiza-

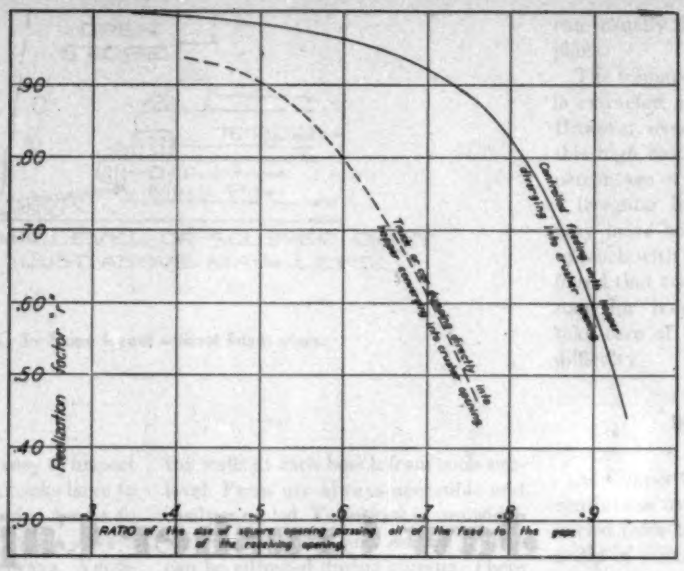


FIG 1—Approximate realization factors for use in the capacity equation.

tion factors slightly higher than those given in Fig 1, inasmuch as minor feed bridging problems are less probable.

The Equation

The results of the laboratory and field tests are summarized in the following equation, which can be applied directly where the crushing plates are straight, and either corrugated or smooth:

$$C = f \cdot d \cdot w \cdot y \cdot t \cdot n \cdot a \cdot r \quad [1]$$

where

C is the capacity in short tons per hour through the crusher.

f is the feed factor, dependent upon the presence of fines in the feed, and the surface character of the jaw plates used.

Values of "f"

	Smooth Plates	Corrugated Plates
With normal fines	0.0000414	0.0000305
Fines scalped out	0.0000364	0.0000254
Large pieces only	0.0000312	0.0000207

d is the apparent density of the broken product in pounds per cubic foot. (If the true specific gravity is known, 40 pct voids may be assumed and d becomes 37.4 times the specific gravity of the ore.) This is shown in Fig 2.

w is the width of the crushing chamber in inches.

y is the open side setting of the crusher in inches. (This is measured from the lower tip of the swing jaw, and in the case of corrugated plates from the tip of the corrugations on the swing jaw to the opposite valley on the stationary jaw plate.)

t is the length of stroke in inches at the lower tip of the swing jaw plate.

n is the crusher revolutions per minute or crushing strokes per minute.

a is the nip angle factor. It is unity for 26° and 3 pct greater for each less nip angle degree. For example, a nip angle of 20° has an a value of 1.18.

r is the realization factor. It is unity for perfectly uniform choke feeding and usually less for actual operating conditions; according to the feeding method used, and the probabilities of hangups involving the size of feed and the crusher opening. Approximate values are given by the curves in Fig 1. These values are further reduced by intermittent feeding.

Curved Jaw Plate Capacities

If the crushing plates are curved, either corrugated or smooth, the factors given above are the same, with the provision that the nip angle is taken in the portion of the upper chamber which is usually flat. If a continuous jaw plate curvature is employed, the nip angle should be taken in the crushing chamber where the largest pieces in the new feed would lodge at their minimum (slot size) dimension.

An alternate, more complicated method of predicting curved plate capacities is outlined in the text. Accuracy comparisons between the two methods are shown graphically in Fig 8.

Test Work

LABORATORY TESTS

The 10 by 7 in. Blake crusher tests were recorded by means of a 35 mm motion picture camera. This was driven by the crusher through a flexible shaft, thereby synchronizing exposures with the crushing cycle. The camera photographed an instrument panel which contained devices to indicate the crusher speed, cumulative product weight, motor power conditions, the number of the crusher revolutions, and a card identifying the test. Two pictures were taken per revolution of the crusher flywheel. Following several tests, the film was developed and read in a microfilm viewer as a negative, the data being plotted as functions of crusher revolutions.

In plotting the data from the film it was found to be advantageous to have each frame identified by a number so that quick reference could be made to any given period in the test. Accordingly, a revolution counter driven by another flexible cable was placed in view of the camera.

The crusher speed was brought to the instrument panel by means of a

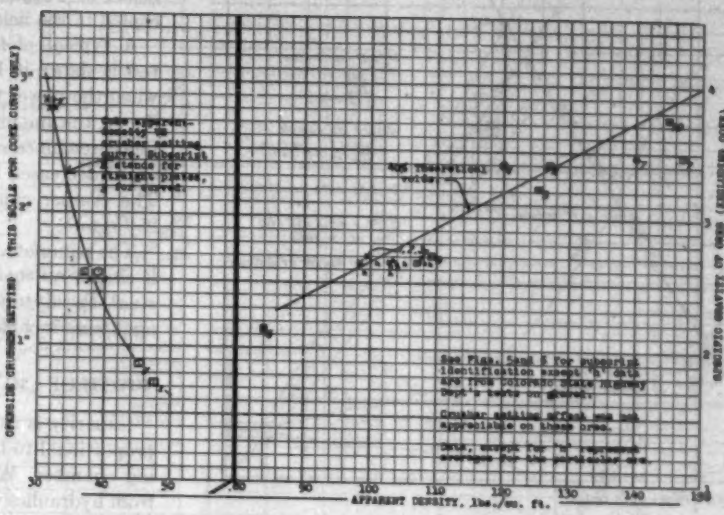


FIG 2—Apparent density of crusher products.

remote indicating tachometer of the generator-voltmeter type. This was very useful in determining the effect of speed on capacity during tests where the speed was varied purposely.

The power requirements of the crusher motor were indicated by a wattmeter. The readings shown by this instrument were plotted along with the capacity curves and aided considerably in their interpretation. These power curves have been integrated with a planimeter to determine the actual kilowatt hours per ton required for crushing.

Several means of continuously weighing the crusher product were tried. The method finally adopted consisted of catching the product in a box on an air-inflated automobile inner tube and interpreting the weight as a function of the increasing pressure of this air. The inner tube was inflated initially to a pressure of about 10 in. of water. The valve stem was connected by a rubber hose to a manometer filled with a colored liquid. The U-shaped manometer tube served to seal the inflating air in the inner tube, as well as to indicate the weight of the crusher product in terms of liquid level.

The particular 6.00 by 16 inner tube used was found to give a uniform weight-pressure response up to loads of at least 150 lb. An arbitrary linear scale was placed alongside the manometer to graduate the column rise.

It was found to be advantageous to determine the rise and equilibrium conditions of the manometer from the data plot, and to recalibrate the weight values of the manometer graduations for each test by weighing the sample after each run. There were slight changes of calibration from run to run, caused either by stretching of the rubber, slight thermodynamic changes of the inflating air, or by disturbance of the apparatus while handling the sample. These changes are compensatory during the test itself but preclude a fixed calibration of the manometer.

About 50 lb of feed were sufficient for most of the 10 by 7 in. crusher tests, and these were recorded on approximately 15 ft of 35 mm film. This amount of film permitted the camera to be started just before the feed reached the crusher, and allowed it to run until crushing was completed and equilibrium conditions were again apparent to the operator.

FIELD TESTS

Where a weightometer or other similar conveyor weighing device is installed in conjunction with a crusher it often may be used to give a continuous record of the weight output, either by photographing the totalizer against time, or by some chart scribing means connected to the weighing beam. In one instance, the settling rate of a large railroad car on its coil springs was photographed against time as it received the product from a 60 by 48 in. crusher directly overhead; the relationship was found to be sufficiently linear for interpretation. These methods and field applications of the inner tube method were used to obtain data to check the extrapolation of trends established in the laboratory work.

In preparation for a test the crusher bearings were allowed to warm up for at least a half hour by running idle. The samples were choke-fed by hand to the smaller crushers, while the larger crushers were choke-fed by collecting a sample on the apron feeder with which each was equipped.

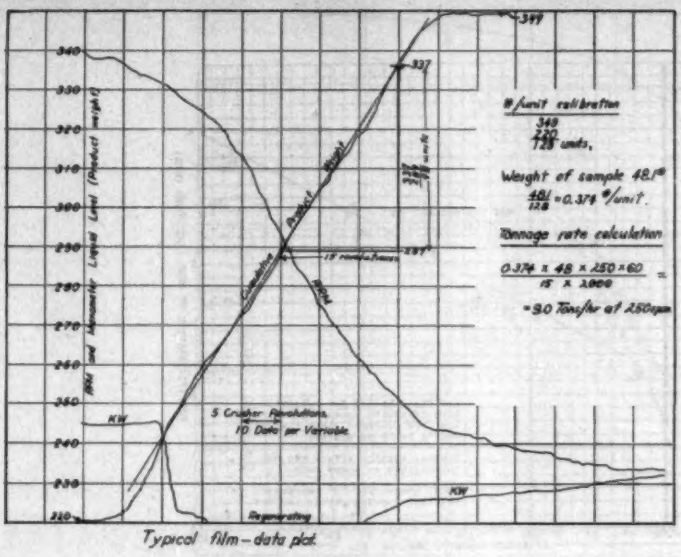
Test Interpretations

While several of the factors influencing crusher capacity have been established by various investigators, several more have been considered as still open questions.[1] Since one of the prime objectives of this investigation concerned the influence of jaw plate curvature on capacity, it was deemed expedient to review the entire situation in as much detail as possible, so that effects caused by curvature could be evaluated as such. Fortunately, most of the variables were either confirmed or found to be directly proportional to the capacity. The few deviations from this were not serious, and proportionate assumptions appear to be adequate for all practical purposes.

SPEED

Speed was one of the first effects to be tested. This was done by driving the crusher with a variable-speed direct current motor and varying the crusher speed during the test run. The speed range extended from about 40 pct above normal to about half speed.

[1] References are at the end of the paper.



Typical film-data plot.

FIG 3—Typical film-data plot.

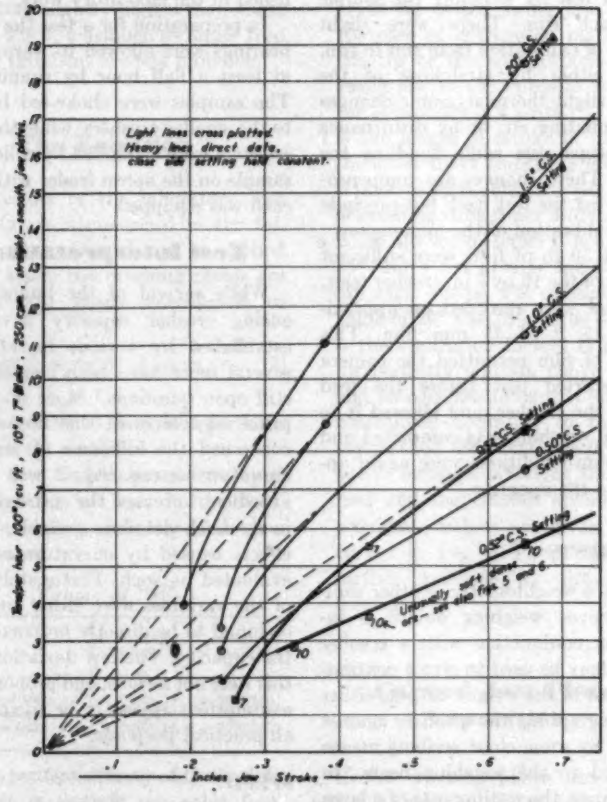


FIG 4—Jaw stroke effect upon capacity.

As previously outlined, the camera was synchronized with the crushing cycle, and when the cumulative weight output was plotted it became a practical indication of the output per revolution. These data were found to be substantially constant for several materials and plate curvatures. It follows that for normal jaw crusher speeds, capacity is proportional to speed. This agrees with Hersam's formula published in Taggart,[1] and is usually accepted in the field.

A typical plot of a variable speed test is shown in Fig 3. It is noted that when the power to the crusher was reduced, the amount of product per revolution remained constant as the crusher speed decreased from 335 to 254 rpm. The crusher capacity was 9.0 tph at 250 rpm.

The cumulative weight curve shown is similar to that of many of the constant speed tests, particularly where fines were included in the feed.

WIDTH OF CRUSHING CHAMBER

Capacity is usually considered to be proportional to the width of the crushing chamber. While certain analogies from hydraulics would seem to indicate a slightly greater than proportional increase, this deviation is apparently negligible, since a proportional assumption resulted in successful reduction of 60 by 48 in. and 26 by 19 in. crusher data to equivalent 10 by 7 in. data (Fig 5). Capacity is, therefore, considered to be proportional to the width of the crushing chamber.

JAW STROKE

The length of the jaw stroke in the 10 by 7 in. Blake laboratory crusher was varied by raising and lowering the rear toggle seat. The resulting effect of stroke on capacity was analyzed by cross plotting data corrected to common conditions of speed, nip angle, and settings, and by running a series of tests where the close-side setting was held constant and the stroke varied.

A typical cross plot, that of the straight-smooth plates, and also direct data, are given in Fig 4. It is evident that above a practical minimum, capacity is directly proportional to stroke.

SETTING

All of the laboratory capacity data obtained with normal jaw strokes were corrected for minute differences of stroke, characteristic of the toggle system at various settings, to a mean of 0.65 in. They were also corrected for product density to 100 lb per cu ft and for differences in speed to a common base of 250 rpm.

These data so corrected were plotted as a function of open-side setting and capacity. Fig 5 and 6 concern straight plates and when extensions are made of similar feed conditions it is evident

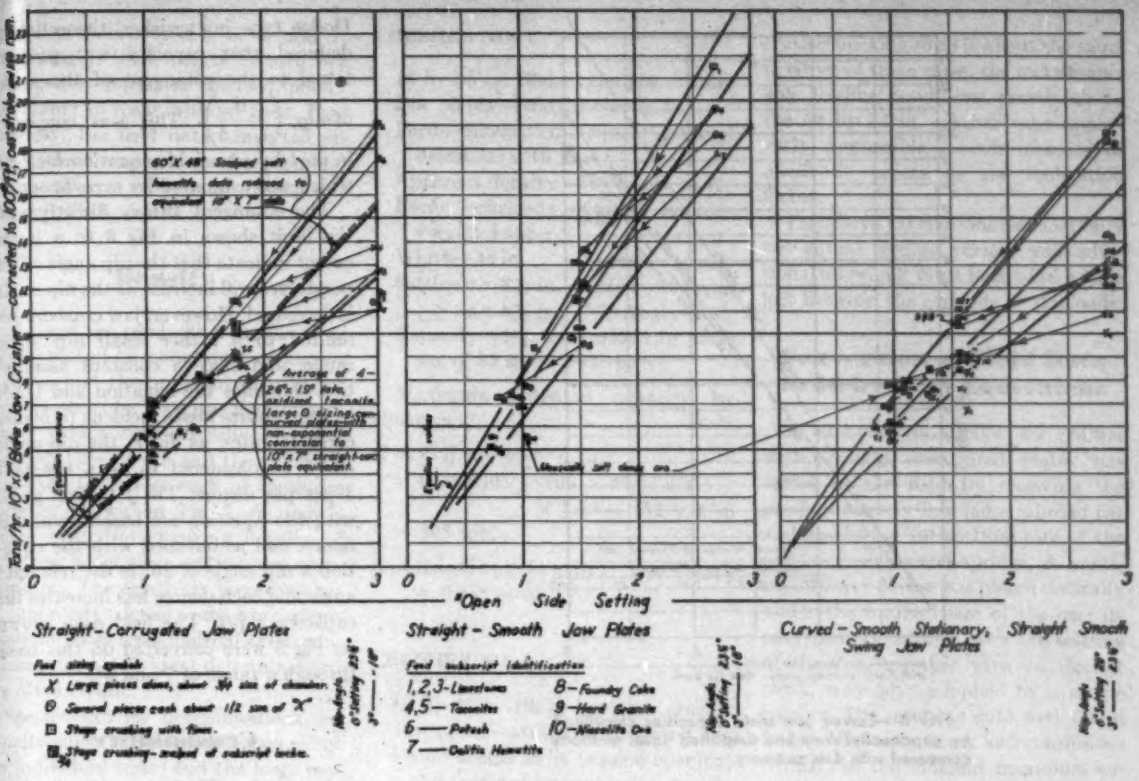

Tons/hr 10"x7" Blake Jaw Crusher—corrected to 100 RPM, eccentric throw 1/4"
"Open Side Setting
Straight-Corrugated Jaw Plates
Straight-Smooth Jaw Plates
Curved-Smooth Stationary, Straight Smooth Swing Jaw Plates
Feed setting symbols
X Large pieces alone, about 3/4 size of chamber.
O Several pieces each about 1/2 size of "X"
Shape crushing with fines.
Shape crushing-analysed at subscript index.
Feed subscript identification
1,2,3-Limestones
4,5-Taconites
6-Potash
7-Cuba Hematite
8-Foundry Coke
9-Hard Granite
10-Nickeliferous Ore
Average of 4-28% 18" Nata, oxidized Taconite. Large O sizing, curved plate with non-exponential conversion to 10"x7" straight-jaw plate equivalent.
Hi-Angle 25° 3" setting 1/8"
Hi-Angle 25° 3" setting 1/4"

FIG 5 FIG 6 FIG 7

FIG 5–7—Summary of laboratory and converted field data plotted as open-side setting vs. capacity.

that these pass through the origin, and hence, *straight plates have a proportionate setting-capacity function.*

Fig 7 is the summary plot of laboratory data obtained with smooth-curved plates. These plates were constructed with a full exponential curvature in the lower zone to emphasize the curved plate characteristics which are generally regarded as desirable. Setting for setting, these curved plates had the same gape and the same depth of crushing chamber as the straight plates, but the nip angle of the upper chamber was 5½° greater. (For most applications this amount of curvature is not required or used, but by analysis we can predict with fair accuracy what the performance of plates having a lesser degree of curvature would be.)

The setting-capacity curves on Fig 7 are apparently exponential, and an attempt follows to predict the effect of plate curvature on this basis.

Fig 8 is a composite graph showing the "with fines" capacities of straight-smooth plates and also curved-smooth plates. The actual data are shown in heavy lines while the synthesized data are in light lines. In this graph it may be seen that beyond a setting of about 1 in. the curved plates have a tested capacity less than that for the straight plates. It may be reasoned that if a succession of jaw plates are considered having less and less curvature but the same gape and setting, they would begin to have the same nip angle in the upper chamber and also the same capacity characteristics as the straight plates. Accordingly, the straight plate capacity may be used as a maximum reference and the curved plate capacity approximated by a skew function.

In computing a factor for the skew analysis it may be seen that to conform, it can be of exponential type and fortunately of relatively small degree variation. Accordingly, an exponential consideration is made of the open-side setting with the degree controlled by the percentage of nip-angle change.

The corrective factor just discussed becomes:

$$\frac{y^x}{y} \qquad [2]$$

where y is the open-side setting and x the decimal expression of the percentage of nip-angle difference between the straight plate and curved plate crushing chambers of equal setting and gape.

As an example of the application of this factor, the calculation of the capacity of the curved plates tested in the 10 by 7 in. crusher is made at an open-side setting of 3 in., using the straight-smooth plate data obtained at 3 in.

$$y = 3$$
$$x = 18/23.5 = 0.766$$
$$\frac{3^{0.766}}{3} = \frac{2.34}{3} = 0.78$$

The straight plate capacity at 3 in. is 25.0 tph. The curved plate capacity becomes 25.0 times 0.78 or 19.5 tph. By plotting 19.5 tph on Fig 8, at the 3 in. setting and other points, it is evident that the accuracy of the method is sufficient for most settings. The *X*'s on Fig 8 represent skew points that have been calculated.

This method of skew computation requires that the straight plate dimensions of the crusher be known before

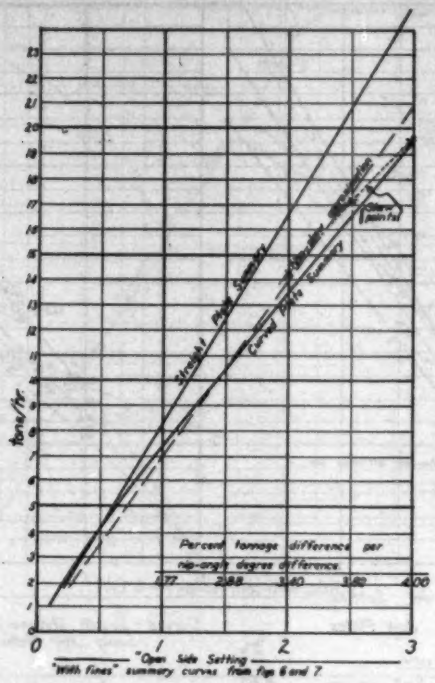


FIG 8—Curved jaw plate capacities calculated by exponential skew and simplified linear methods compared with data summary.

the straight plate capacity potential can be calculated and converted to curved plate equivalents by factor (2).

The foregoing method may not be particularly convenient in the field, and it is suggested that practical results may be obtained by merely applying the equation as listed at the discharge of the curved plate chamber but taking the nip angle from the upper portion of the crushing chamber. Using this latter approximation the straight-smooth plate data are converted on the basis of 3 pct per degree nip angle and are included on Fig 8. Here it may be seen that this more convenient method has relatively high useful accuracy.

Where a continuous plate curvature is employed from the top to the bottom of the jaw plates it is suggested that the nip angle be taken at a point in the chamber where the opening is small enough to lodge the largest pieces of the feed, since the breaking capacity of the upper chamber appears from the foregoing to have an almost integral effect on the overall crusher capacity.

Nip Angle

The nip angle effect was tested directly by blocking straight plates at various angles in the 10 by 7 in. crusher. While these tests had evidence of high accuracy they are relatively few in number, and reference is made to Fig 8 in order to obtain what corroboration may be had.

General consideration of Fig 6 and 7 indicates that the breaking capacity of the curved plates used in Fig 7 is not sufficient to supply the increased capacity capabilities of the discharge section, which has a much more capacity-conducive nip angle. Accordingly, the curved plate chamber becomes to all intents and purposes a straight plate chamber, at least in the larger settings, with the provision that the effective nip angle in this case is about 5½° larger. Because of this the difference in the two direct data curves on Fig 8 can be evaluated in terms of percentage of capacity per degree of nip angle difference. These values have been calculated for several points and are included in Fig 8 above the setting to which they apply. It is evident that these figures approach a limit a little over 4 pct per degree, which tends to confirm approximately the 3 pct per degree value found in the direct nip angle tests from 18 to 24°.

Hersam,[2] working principally with a Dodge type jaw crusher, theoretically deduced that capacity was proportional to the cotangent of the angle of nip, $\left(\frac{d}{e-b}\right)$. This was corrected in part by a variable equation factor k which was evaluated by experiment.

The cotangent theory directly and the limit shown in Fig 8 to a lesser extent indicate that the nip angle effect per degree will increase as the nip angle is decreased. However, jaw crushers are limited to a rather small nip angle range, and since a constant assumption simplifies the equation and tends to compensate losses incident to higher capacity rates, as did k, the nip angle effect is considered to be a constant 3 pct per degree. The f factors given with the equation are based upon this figure, and as outlined with the equation a nip angle of 26° is the reference angle and each degree less increases the capacity 3 pct. The field data shown on Fig 5 were converted on this basis through a range of 7 and 8°.

Crushability

As noted on Fig 5, 6, and 7, the data plotted have been corrected to common conditions of speed (250 rpm), stroke (0.65 in.), and apparent density of the product (100 lb per cu ft), but not for an equally wide variety of hardnesses and ore strengths. The lack of a "crushability-capacity" trend is obvious within a relatively small band of experimental error. (Particular reference is made to the points representing feeds with fines.) Since a considerable number of combinations and wide ranges of hardness and density were tried in the tests it seems reasonable to disregard the effect of feed strength or hardness on capacity.

Feed Factors

Tests made with feeds containing the fines resulted in smoother operation and more continuous product weight curves plotted from the film data. These tests were quite reproducible as evidenced on Fig 5, 6, and 7. Feeds without fines often had minor interruptions which necessitated that an average be taken on the plotted cumulative weight curve of the test. While the nature of these interruptions was portrayed by the shape of these curves, which greatly assisted in determining a mean, these averages were not too definite and resulted in a fairly wide

spread of points on Fig 5, 6, and 7. Accordingly, these points in turn are averaged to determine the feed factors pertaining to feeds without fines. Fortunately, the field data converted on Fig 5 corroborates these feed factors, which take a fairly uniform spread through Fig 5, 6, and 7.

Density

Most of the products from the tests were weighed in a container of known volume, and the apparent density, or pounds per cubic foot was determined. These values were carefully averaged for each type of ore and the resultant was used to correct each of these ore varieties shown on Fig 5, 6, and 7, where even the changing density of coke due to crusher setting was compensated. The relatively large number of apparent density determinations made in these tests assisted the evaluations, since individual determinations are often erratic.

Specific gravity determinations are usually more consistent and convenient for individual tests, and the large majority of broken ores have been found to have about 40 pct voids. Accordingly, substitution may be made of the apparent density factor in the equation for most ores by the following equivalent:

$$d = (62.4 \times 0.60 \times \text{sp gr of ore}) = (37.4 \times \text{sp gr of ore}) \quad [3]$$

While this substitution may be more convenient, experience has shown that there are some exceptions. Fig 2 is included for convenience on this topic.

Realization Factors

Assuming that the angle of nip is adequate, and that the feed is of the usual type and does not tend to pack excessively, the equation, exclusive of the term r represents the maximum potential capacity of the crusher. In actual practice this figure will seldom be obtained, but will be reduced by interruptions incident to hangups and other conditions resulting in intermittent feeding. Curves giving approximate realization factors for several conditions of feeding have been included in Fig 1.

Two unusually complete sets of crushing data are given in the literature by Sheppard.[3] These are substituted in Eq 1 which is then solved for realization factors characteristic of the installations.

CRUSHER NO. 1

48 by 36 in. Blake type jaw crusher
Jaw plates—straight corrugated
Feed—minus 24 in. (square opening) limestone with fines
Apparent density—106 lb per cu ft
Feeder—carloads dumped in converging hopper
Width—48 in. Swing—1½ in.
Setting o.s. 8⅜ in. Speed—155 rpm
c.s. 6⅞ in. Nip Angle—26°
Capacity—4½ ton carload in average of 85 sec = 191 tph

Maximum potential capacity by equation:

$$C = f \cdot d \cdot w \cdot y \cdot t \cdot n \cdot a$$
$$= 0.0000305 \times 106 \times 48 \times 8.375 \times 1.50 \times 155 \times 1.00$$
$$= 302 \text{ tph.}$$

Realization factor, $r = {}^{191}/_{302}$
= 0.632 or 63.2 pct.

CRUSHER NO. 2

60 by 48 in. Blake type jaw crusher
Jaw plates—straight corrugated
Feed—minus 34 in. (square opening) fine grained gray biotite granite with fines
Apparent density—108 lb per cu ft
Feeder—skip loads discharged directly into crusher
Width—60 in. Swing—1¼ in.
Setting o.s. 7½ in. Speed—167 rpm
c.s. 6¼ in. Nip angle—24½°
Capacity—11,615 lb in 70 sec = 299 tph
Maximum calculated capacity:

$$C = f \cdot d \cdot w \cdot y \cdot t \cdot n \cdot a$$
$$= 0.0000305 \times 108 \times 60 \times 7.5 \times 1.25 \times 167 \times 1.045$$
$$= 323 \text{ tph}$$

Realization factor = $r = {}^{299}/_{323}$
= 0.925 or 92.5 pct.

The 48 by 36 in. crusher was fed by a car dumping sideways onto the slope of a hopper converging into the receiving opening.* Since the car was actually longer than the crusher opening width, the descending feed was crowded and subjected to hangups and interruptions in its entry into the crushing chamber.

The 60 by 48 in. crusher was fed by a skip which discharged directly into the receiving opening.* The skip opening was smaller than that of the crusher and the skip itself served to shape the feed ideally for entry into the crusher. Even though the size of feed to size of crusher opening ratio is about the same in either of these cases, the more favorable feeding conditions pertaining to the 60 by 48 in. crusher were apparently responsible for an increase of about 30 points in the realization factor.

The above calculations consider only the actual feeding period, and additional allowance must be made for time lost between the carloads or skiploads.

Conversion of Field Data to 10 by 7 in. Equivalent

A 60 by 48 in. Blake jaw crusher with straight corrugated plates was tested in the field by receiving the product directly in a large railroad car and measuring the settling rate of the car body on its coil springs. A multiplying lever device was placed centrally under the bridge beam of the car; its movements resulting from the settling of the car, together with an electric clock, were photographed by a movie camera. The resulting data were found to be sufficiently linear and continuous to disclose the inherent maximum capacity of the crusher at the tested conditions.

This crusher was found to have a measured uninterrupted maximum capacity of 466 short tons per hour, while crushing scalped hematite weighing about 155 lb per cu ft. The width of the chamber was 60 in., the open side setting 8.0 in., the stroke 1.44 in., the speed 163 rpm, and the nip angle 25°.

In converting this capacity to 10 by 7 in. maximum equivalents we consider the following conditions in the 10 by 7 in. crusher:

100 lb per cu ft material
10 in. crushing chamber width
3 in. open side setting
0.65 in. stroke
250 rpm
a nip angle of 18° at this setting.

(Both crushers are equipped with straight corrugated jaw plates.) The equivalent capacity of the 10 by 7 in. crushers is calculated as follows:

$$C_{10 \times 7} = 466 \times 100/155 \times 10/60 \times 3/8 \times 0.65/1.44 \times 250/163 \times 1.21 = 15.7 \text{ tph.}$$

Because of the linear character of the factors, this point may be joined by a straight line with the origin as shown on Fig 5 to determine approximately equivalent capacities at settings of less than 3 in.

It should be noted that Sheppard's

* Private communication.

tonnage data were average operating performances exclusive of the loss of time between car or skip loads, and included realization factors characteristic of the installations. The tonnage figure of 466 obtained with this crusher was the maximum inherent capacity. The average capacity for the whole test indicates an experience factor of about 95 pct, which is consistent with the size of feed and feeding conditions, that is, feed size to crusher gape ratio of about 0.5 to 0.7, apron feeder, and nonconverging hopper.

The 26 by 19 in. crusher data shown on Fig 5 were obtained by a field application of the inner tube method. They were converted on a factor basis similar to the above calculation. The nip angle of the upper chamber was 26° and the product weighed about 122 lb per cu ft. Tests were made at open side settings of 3¼ and 2½ in. The converted data of different test runs were 12.7, 14.3, 11.4 and 13.0 tph at the 10 by 7 in. crusher setting of 3 in. The plot on Fig 5 is an average of these converted tonnages.

Other Characteristics of Crushing Chambers

While this paper is principally concerned with the tonnage rates of various Blake type crushing chambers it would seem to be worth-while to deviate at this point and go briefly into some of the other characteristics.

CURVED JAW PLATES AND PACKING RELIEF

Apparently most ores have physical properties which permit crushing with straight jaw plates at practical settings and strokes without compaction. A few seem to have difficulty in this respect. Particular attention is called to ore No. 10 and its plotted position in Fig 4, 6, and 7. This ore was unusually dense, relatively soft, and had minute interlacing, slightly malleable veinlets. When tested with straight plates, pancaking, loss of expected capacity and excessive power consumption occurred.

When this ore was tried with the curved jaw plates at the same setting and stroke no difficulty was experienced, the power consumption and capacity being normal.

Similar experience has been encountered in the field,* and it is accordingly believed that the use of properly curved jaw plates tends to alleviate packing in these unusual cases.

The design of optimum curved jaw plates requires considerable planning since the upper chamber nip angle may be excessively increased, resulting in loss of capacity and receiving opening without commensurate benefits. Most of the modified jaw plates now offered utilize curvature at one or both ends and a flat surface at the upper or center portion. Both ends are sometimes curved to permit reversibility, to prolong the wearing life with some loss in the effective receiving opening.

It may be stated briefly from the unpresented power and screen analysis data obtained in the tests, that the curved jaw plates could be set up closer than straight plates for a given motor load. The largest particles produced at equal settings of straight and curved plates have about the same size and shape; however, the fines produced with curved plates have a larger average particle size.

In some instances greater wearing life has been observed for curved jaw plates, which may result from distributing the zone of intensive wear over a larger area. In drawing strict comparisons between straight and curved jaw plates it should be noted from the preceding paragraph that straight jaw plates do more crushing per ton of product at a given setting than curved jaw plates.

CORRUGATED JAW PLATES

Corrugated jaw plates, while characteristically having less capacity, produce a considerably more cubical product which may bring a premium price or be otherwise more desirable. They tend to make a finer product than smooth plates at the same setting, with a corresponding decrease in capacity. Abrasive feed may cause rapid wear of the corrugations.

UNUSUALLY DEEP CRUSHING CHAMBERS

While unusually deep crushing chambers have the advantage of a smaller nip angle, this type of chamber also may be seen to have setting-stroke ratios at various chamber levels which are especially favorable for the use of properly curved jaw plates. Also, because of this additional depth, curvature may be developed in the lower chamber without appreciable sacrifice of upper chamber nip angle.

The capacity equation as given is applicable to these unusually deep chambers. It should be noted that, in addition to the capacity increase due to the nip angle factor, the operating realization factor would probably be slightly higher than usual because of the more favorable upper chamber receiving proportions.

Summary

The choice between types of jaw plates for any specific crushing application may be influenced by some of the following factors:

1. Abrasiveness of the feed material.
2. Fines distribution desired in the product.
3. Mineral unlocking at coarse sizes.
4. Cubical product desired.
5. Maximum receiving opening desired.
6. Tendency of the feed to pack in the crusher.
7. Nipping angle required (slippery feeds).
8. Capacity desired.

The overall problem of jaw crushers is seen to be involved, but in some cases there are worthwhile economies to be had through selection of proper crushing plates. It is evident that application should be guided by tests or experienced judgment.

Acknowledgment

In conclusion, the writer would like to express appreciation for the fine cooperation of his associates in the company and the operating companies in the field, who from the first appreciated the possibilities of the investigation and gave every assistance toward its completion. Particular acknowledgment should be given to Fred C. Bond and Fred R. Gruner who also contributed invaluable guidance in the preparation of this paper.

The opinions expressed on the controversial subject of crushing are those of the writer, and do not necessarily coincide in all particulars with those of other members of the Allis-Chalmers staff.

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Pretreatment of Mineral Surfaces for Froth Flotation

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By S. A. FALCONER,* Member AIME

Introduction

Much attention and publicity has been given, during recent years, to grinding, classification, flotation, and thickening. The various technical papers, and symposiums held to discuss these important phases of milling, have contributed to a better understanding of the fundamental principles and operating variables involved. Another important part of milling—to the flotation operator—is a treatment step to which frequently too little attention is given—"conditioning," or the treatment the ground mineral pulp receives before it enters the flotation machines.

"Conditioning" is a hackneyed and frequently misused term, commonly employed to describe the pretreatment of surfaces of minerals in ore pulps or mill products prior to froth flotation. In general, such pretreatment is for the purpose of changing the flotation characteristics of these mineral surfaces to enable them to respond in some desired predetermined manner when subjected to flotation. Taggart[1] states that the function of conditioning is "either to insure selective collector coating of one mineral species while another species is not; or to take such steps as will compensate for departure therefrom."

As O. C. Ralston has stated:[2]

> . . . we are still faced with the fact that some mineral particles are water-avid, others air-avid, and that by properly modifying them they may be enhanced or diminished in desirable or undesirable avidity. Coatings on minerals must still be assumed to fall into three classes:
>
> (1) a coating of immiscible oil,
> (2) a layer of adsorbed substance,
> (3) a chemically produced coating.

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TP 2593 B. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Aug. 30, 1949. Manuscript received Nov. 29, 1948.

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[1] References are at the end of the paper.

It is submitted that the process of preparing mineral surfaces for subsequent flotation treatment should take into consideration physical as well as chemical means for altering the normal flotation response of the mineral surfaces. A more descriptive word than "conditioning" is needed to designate broadly these procedures.

The minerals in many ores cannot be made to respond in a normal manner to usual methods of "conditioning" with selectivity modifying reagents, until they have been cleansed, or interfering slimes and soluble salts have been removed from the ore. Therefore, it appears important to include under the general subject of "conditioning" a discussion of the purposes, methods used, and some of the advantages of these pretreatment steps. This is dealt with under the subject heading "Initial Treatment of Mineral Surfaces and Ore Pulps."

Under this broader interpretation, the methods employed for treating mineral surfaces to alter their flotation characteristics may be divided into three general classes:

1. Physical methods.

2. Chemical methods.
3. Combination of physical and chemical methods.

PHYSICAL METHODS

These include:

1. Scrubbing or attrition grinding to remove surface stains or alteration products from mineral surfaces to assist action of chemicals in subsequent pretreatment and flotation steps.

2. Desliming to remove interfering slimes or soluble salts prior to introduction of chemical reagents to assist flotation.

3. A combination of scrubbing followed by desliming prior to subsequent chemical treatment.

4. The mechanical means used to bring reagents in contact with mineral surfaces.

CHEMICAL METHODS

These include:

1. Addition of surface *cleansing* agents such as acids or alkalies to assist the removal of surface stains and alteration products prior to treatment with other reagents whose function is to modify further the normal flotation response of the mineral surface.

2. Corrective agents to prevent formation of slime coatings, or assist dispersion of other reagents.

3. Addition of surface modifying agents to activate or depress the mineral in the subsequent flotation step.

4. Addition of promoters and frothers to float the selected mineral or minerals.

ADVANTAGES OF PRETREATING PULPS BEFORE FLOTATION

These may be listed as follows:

1. Improved metallurgical results due to better contact between mineral surfaces and reagents. Also, apparatus used for pretreatment can provide sufficient capacity to level out minor inequalities in rate of feed and characteristics of the ore.

2. Reduction in reagent consumption.

3. Reduction in time required to complete reactions between reagents and mineral surfaces.

4. Reduction in number of flotation machines.

5. Possibility for more intimate contact and better spreading of reagents which are viscous and poorly soluble in water, for example, treatment of phosphate rock with fatty acid and fuel oil.

Initial Treatment of Mineral Surfaces and Ore Pulps

DESLIMING OR WASHING FOR REMOVAL OF SLIMES, COLLOIDS, AND/OR SOLUBLE SALTS

Most ores contain alteration products either in the form of soluble salts or colloids. If these are present in appreciable amounts, they may interfere with flotation and must be removed. The soluble materials may react chemically with the minerals in the ore and interfere with flotation. The colloidal material and slimes can interfere in a number of ways, namely, (1) by consuming reagents—thus decreasing separating efficiency and increasing the cost of treatment, (2) by forming coatings on other minerals and thus preventing their selective separation by flotation, or (3) by diluting the grade of the concentrate. Flocculated colloids or slimes can also interfere by enclosing fine particles of valuable mineral and thereby preventing recovery of the latter.

Slimes

In the discussion following presentation of a paper[3] given at the February 1930 meeting of the AIME in New York, the opinion was expressed by Prof. A. F. Taggart and Prof. A. W. Fahrenwald that difficulty in floating overground sulphides is not due to fineness *per se* but is from primary slimes which adhere to the sulphide particles and prevent adherence of the mineral to an air bubble. At the time, Professor Taggart observed that in general, when the surfaces of sulphide particles are slime-coated there is poor flotation, and that a reagent that affects and lessens the slime coating generally aids flotation. Commenting further, he described certain experiments with pure galena in distilled water into which was introduced a suspension of ground quartz. The latter did not coat the galena, but when a small amount of lime was added a firmly adherent layer of quartz particles formed on the galena and prevented an air bubble from attaching to the latter. On the other hand, when the clean galena particles were placed in a distilled water suspension of slime from run-of-mine Anaconda ore it was found that a bubble would not adhere to the galena surfaces in the presence of a collecting agent, but the addition of lime freed the surface of slime and permitted flotation.

G. R. M. Del Giudice[4] in a discussion of the effects of slimes on flotation, reports that:

> . . . experiments indicate that the mechanism of slime coatings may be due to a reaction between anchored ions on the mineral surfaces to give a relatively insoluble compound which will then act as the cement between the slime particles and the minerals. The reagents which inhibit slime coatings seem to be those which react with the surfaces of either the mineral to be floated or of the slime particles, to form thereon compounds which are less soluble than the compound formed by the interaction between the soluble collecting agent and the salt or salts present at the mineral surface. Inasmuch as the chemical composition of different ores varies, and the slime-coating inhibitors apparently function by chemical reaction, that these reagents must in general vary with the ore seems clear. Water glass, however, appears universally applicable to sulfide ores on account of the relatively low solubility of metal silicates.

In the treatment of sulphide ores containing interfering slimes, it is usually possible to overcome or minimize their effect by the use of proper controlling reagents. This procedure is not always possible or economical in the case of nonmetallic ores, where the promoter reagents used are normally less selective. Where the slimes virtually inhibit flotation, as in the case of raw Florida phosphate rock, desliming is the accepted practice. Where slimes cannot be discarded, conditioning to render either the slime or the mineral particle too insoluble to permit the cementing reaction discussed in Del Giudice's paper[4] is indicated.

In an interesting paper,[5] S. G. Bankoff postulates that the conditions that control the flocculation of mineral particles in water are the same as those that control slime coating. Evidence is presented to show that slime coating is inhibited whenever the slime particles are ionized sufficiently for Brownian movement to occur and is facilitated when they are not. Both slime coating and flocculation are further aided by water-repellent surfaces on the adhering particles. Adhesion occurs when one surface is coated with a substance that is known to react with the other surface to make it water-repellant or when both surfaces are water-repellant. Gelatin accelerates both slime coating and flocculation tremendously.

Interfering slimes are usually dealt with by desliming in an apparatus such as a hydroseparator, or a bowl classifier.

Recent experiments indicate that the newly-developed Dutch State Mines cyclone thickener may also have application for this purpose.

Various investigators have also proposed the use of a preliminary, selective flotation step to remove interfering slimes from nonmetallic ores, prior to further flotation treatment.

Where separate sand-slime flotation treatment is to be used, it is important in laboratory testing to avoid making tests on samples that have been wetted and then dried or allowed to stand in the form of a pulp for more than a few hours.

An excellent discussion of the advantages of washing and desliming flotation feed is given by A. L. Engel.[6] He cites a number of instances where improved results were obtained by removal of colloidal slimes from the ore. For example, slow elutriation for removal of colloids from a copper ore ground to flotation size resulted in an increase in recovery from 65 to 90 pct. In elutriation, only 1½ g of material was removed from a 1000 g sample. This removed material consisted almost entirely of colloidal silica which had interfered with the flotation of fine particles of bornite.

The extensive studies in connection with the influence of colloids in flotation, conducted by the late W. O. Borcherdt during his association with The New Jersey Zinc Co., should be mentioned. The industry has profited from his valuable work.

Soluble Salts

If present in excessive amount, interfering soluble salts must be removed by washing and filtration, or by countercurrent decantation methods.

It is well known that soluble salts in ores can have a pronounced effect on flotation. Soluble copper salts interfere with selectivity when treating complex copper-lead-zinc sulphides. Zinc sulphate is sometimes troublesome in the treatment of some lead-zinc ores because it interferes with zinc recovery and requires larger amounts of activating agents and promoters. Ferrous, ferric and aluminum sulphates also interfere in flotation of sulphides. In connection with these latter reagents, A. W. Hahn reported[7] that burnt lime eliminates to a large extent the deleterious effect of ferric and aluminum sulphates, but offsets to only a small extent the effect of ferrous sulphates. To eliminate the effect of the latter, he proposed the use of an oxidizing agent such as oxygen, chlorine, or chloride of lime, added to the ore pulp in the presence of burnt lime.

Discussing this subject from another angle, N. H. McKay states[8] that whereas he has noted numerous articles relating to the effect of harmful salts in flotation and the research and mill experiments that have been carried out to obviate their effect, apparently nothing has been published on the *beneficial* effect of the soluble constituents. In this connection he discusses the opportunity of utilizing soluble zinc salts in the treatment of lead-zinc ores to depress zinc, and also to offset the effect of slimes which may protect sphalerite surfaces from surface oxidation. He also cites the apparently beneficial effect of ferrous sulphate in conjunction with cyanide or alkaline sulphites for depressing pyrite during flotation of chalcopyrite in ores mined at the Matahambre Property of the American Metal Co., in Cuba.

CLEANSING OF MINERAL SURFACES BEFORE FURTHER TREATMENT

The beneficial effects to be derived from cleansing of mineral surfaces prior to further treatment with reagents ahead of flotation are set forth fully in an excellent paper[9] by J. E. Norman and O. C. Ralston presented at the February 1939 meeting of the AIME in New York. In this paper the authors express the opinion that:

> . . . experimenters spend too much time seeking new flotation reagents that will give more selective filming, when actually their troubles are due rather to impurities that either mask the true mineral surface or act as activators on surfaces of minerals that are not to be floated.

Using this philosophy as a basis, the authors investigated two general methods of cleaning contaminated surfaces:

1. Chemical preparation,
2. Attrition milling.

These authors define chemical preparation as consisting of washing the flotation feed with solutions of dispersing and/or complexing reagents such as hydrofluoric acid, phosphoric acid, fluosilicic acid, sodium hydroxide, tetrasodium pyrophosphate or sodium cyanide. They report that hydrofluoric acid gave best results in most tests because of its ability to form complexes, with many heavy metal ions and to "loosen" slime.

J. W. Johns, discusses[10] the effects of surface films on metallic gold. The addition of caustic soda (to change the pH to 8.2) or sulphuric acid, apparently removed this film and permitted better recovery. However excess sulphuric acid (above 5 lb per ton) greatly retarded flotation, 74 pct recovery at 5 lb per ton (pulp pH 6.8) to 5.6 pct recovery at 6.0 lb per ton (pulp pH 4.0). On the other hand, caustic soda in amounts up to 4.0 lb per ton (pulp pH 10.4) gave increasingly good recovery—94.5 pct.

Attrition grinding or scrubbing is the recommended mechanical method for cleaning mineral surfaces of slime and stains or deposits of salts. Norman and Ralston developed a special type of scrubber, comprising a high speed, rotor-type agitator revolving inside of a cylindrical tank or cell, with baffles mounted around the periphyry of the latter. Using an apparatus of this type, it is possible to scrub the mineral particles by repeated collision of the particles. In cases where the mineral particles may be relatively soft, and the adhering slime or stains are difficult to remove, the addition of a hard, heavy grinding medium such as garnet or zircon may be used. Although Norman and Ralston do not mention it, the use of magnetite or ferrosilicon suggests itself for this purpose, since these scrubbing aids could be readily recovered by magnetic separation from the pulp after completion of the scrubbing operation, and reused.

Other types of apparatus such as blade mills, log washers, washing trommels, vibratory screen scrubbers, and so on, are also employed, or have been proposed, to scrub mineral surface.

A special type scrubber and mud ball disintegrator has been developed by Mead and Maust, formerly associated with Cyanamid's Florida phosphate operations at Brewster. This disintegration apparatus is described in U.S. Patent 2,297,009 and is being used with outstanding success in connection with the flotation operations at Brewster.

In many instances, a combination of chemical treatment and attrition scrubbing is necessary to prepare the mineral surfaces for subsequent contact with reagents required for flotation. Numerous examples are to be found where such treatment has yielded beneficial results, both in the laboratory and in large scale operations. For instance spodumene ores respond well to this treatment, as has been well set forth in a paper by Norman and Gieseke.[11]

These investigators found in their studies of spodumene rocks from six entirely different localities in the United States that:

> . . . difference in behavior of these rocks disappeared after proper cleansing of mineral surfaces and that after this cleaning, spodumene could be froth floated from associated minerals by the use of a number of different reagents.

The cleaning treatment, which varied in intensity according to the nature of the particular rock (the more weathered the material the more strenuous the treatment), consisted of vigorous agitation or attrition of the ground rock in a slurry containing a dispersant, such as sodium hydroxide. After proper cleaning of the crude rock the same flotation treatment, even to approximately the same amount of collector, gave highly selective flotation of spodumene. Oleic acid was considered the best collector for spodumene, from the standpoint of cost and efficiency.

In a recent U.S. Bureau of Mines report[12] by F. D. Lamb, results of investigations on New England beryl ores have shown that these ores were amenable to flotation only after desliming and vigorous surface conditioning with a suitable reagent such as caustic soda, trisodium phosphate, or hydrofluoric acid. Following such pretreatment, fatty acids in the form of emulsions were found to be most satisfactory promoters for beryl.

The benefits obtainable through the use of scrubbing and desliming procedures are well exemplified in the treatment of "Nelsonite" ore at Cyanamid's concentrator and pigment plant at Piney River, Va. At this property, "Nelsonite" ore (a geological term used to describe the weathered ilmenite ores of the district) is treated by flotation for recovery of ilmenite, from which is produced high quality pigment in an adjacent plant. The ore presently being mined is composed of ilmenite associated with apatite, ferromagnesian silicates, and quartz; and contains considerable amounts of kaolin, talc, amphibole, and iron oxide slimes. In order to produce a high grade ilmenite concentrate suitable for pigment manufacture, special procedures are required in the flotation plant to provide essentially complete removal of gangue slimes, and subsequent elimination of apatite in a two-stage flotation process. In this connection, it has been found that as little as 0.5 pct weight of gangue slimes affects flotation to the extent that twice the amount of promoter reagents normally used in treatment of clean ore is required for maximum recovery of ilmenite. In addition to the greater consumption of reagents, the presence of slimes interferes with selectivity.

In order to cope with this slime problem at the Piney River plant, it has been found necessary to adopt a flowsheet comprising initial desliming of the ore after crushing, and further desliming following each of three stages of grinding. This procedure gives effective elimination of slimes and minimum loss of ilmenite with the slimes. Under this system, the grinding units act as scrubbers in addition to freeing ilmenite from gangue.

Other examples include scrubbing and desliming of Florida pebble phosphate, beach sands, kyanite ores, glass sands, and others.

Although these procedures of attrition scrubbing and desliming are not as commonly employed in the treatment of sulphide ores as they are for nonmetallic ores, it is suggested that they warrant more attention than they have received. For instance, in the treatment of sulphide ores containing talc, graphite and similar soft minerals that tend to smear sulphide surfaces during the fine grinding stage, there might be benefits from an attrition scrub in the presence of dispersing agents ahead of further conditioning and flotation.

Discussion of the Principal Variables Involved in "Conditioning" of Previously Prepared Mineral Surfaces

The following interrelated variables (not necessarily in the order of their importance) influence the end results which are obtained when mineral surfaces are pretreated before flotation:

1. Time of treatment.
2. Number of stages of treatment.
3. Percentage of solids in the pulp.
4. Intensity of treatment.
5. Degree of aeration.
6. Temperature.
7. Method and order of addition of reagents employed for flotation.

TIME OF TREATMENT

Time of treatment is important. Too short an interval will not yield desired results. On the other hand, excessive time will result in increased consumption of reagents and power. Frequently, it also may be decidedly detrimental from the standpoint of formation of slimes which interfere with subsequent flotation, or because of destruction of beneficial films on the mineral surfaces.

In the treatment of nonsulphide base metal ores, little or no "conditioning" is usually desirable because the film formed by sulphidizing agents is readily destroyed or transformed.

In the final analysis, the time factor is related to pulp density, temperature of pulp, solubility of reagents, intensity of agitation, speed of reaction of reagents with mineral surfaces, and the state of the mineral surface.

As regards the flotation of quartz, and certain other silicate minerals, with positive ion promoters such as the long-chain amines or quaternary ammonium compounds, Dean and Ambrose[13] state that: "the highest recovery always is obtained . . . by stage addition; that is, an excess of reagent is never permitted in solution." Their experiments show that there is a rapid loss in efficiency when the time of contact between mineral and promoter extends beyond one minute. They suggest that the emulsifying power of the reagents removes water-repellant coatings from the particles if the solution is allowed to become sufficiently concentrated. These observations and experimental results have been confirmed in Cyanamid's Mineral Dressing Laboratories at Stamford, Conn., and at Brewster, Fla. That is little, or no, conditioning, and minimum agitation of feed after contact with the cation promoter, yields best results. In this connection, these facts led to the development of a special technique designated "flash flotation"; and a special flotation machine to put into practice this idea was designed by Mead and Maust, (formerly connected with Cyanamid's Florida phosphate operation) which is now covered in U.S. Patent 2,304,270. Broadly, their invention includes a process which involves the introduction of the ore pulp (previously contacted with reagents) into a flotation cell below the froth area but above the zone of agitation whereupon the ore is subjected to aeration with a minimum of agitation. The floatable portion of the ore material is immediately carried into the froth by the air bubbles, and the tails or nonfloatable material sinks until met by an upward flow of water from the

zone of agitation and is discharged from the cell at a point immediately above the zone of agitation. During the flotation operation the major portion of the ore pulp does not come in contact with any moving mechanical parts and hence there are produced no interfering secondary slimes which are so detrimental to flotation with positive ion reagents.

In the treatment of zinc sulphide ores, it is of interest to note, in connection with this discussion of the time factor, that, according to Mortensen,[14] the time required to activate zinc sulphides with $CuSO_4$ increases with the iron content of the blende and increases with rise in temperature and pH.

NUMBER OF STAGES OF TREATMENT

Number of stages of "conditioning" depends on the type of flotation separation desired. Normally, at least two tanks are desirable, to avoid short-circuiting. Two or more tanks or cells also permit flexibility in order of addition of reagents, adjustment of pulp density if desired, and variation in intensity of action if required between one stage and the next, and so on. However, if the "conditioning" operation is a simple one, and conservation of space is essential, a single tank may suffice.

PERCENTAGE OF SOLIDS

Pulp density is a critical factor in connection with the treatment of many types of ores—particularly in nonmetallic flotation. Coarse mineral pulps are more easily maintained in suspension at high solids than at low solids. In "conditioning" sulphide ore pulps it is usually desirable to conduct this operation at high solids because of greater concentration of reagents per unit volume of pulp and conservation in size of equipment required. For example in the activation of zinc sulphide, 1 lb of copper-sulphate per ton of ore at 50 pct solids means 1 lb of copper-sulphate per ton of solution whereas at 20 pct solids the quantity of copper-sulphate per ton of solution is only 0.25 lb. In addition, the volume occupied by 1 ton of pulp at 50 pct solids is less than ⅛ of the volume occupied by 1 ton of pulp at 20 pct solids. In other words, conditioning apparatus would have to be more than three times as large to provide the same time of contact of reagents with the pulp at 20 pct solids as it would for pulp at 50 pct solids.

Some slimy types of ores, particularly those containing bentonite, cannot be conditioned at high solids because the pulp becomes too viscous for proper dispersion of reagents, especially if the latter are poorly soluble or viscous themselves.

In the flotation of many nonmetallic ores with anionic-type promoters such as fatty acids, or soaps, greatly improved results are obtained, also savings in reagents can be effected, if the reagents are conditioned with pulp at high percentage of solids. This is particularly true when treating coarsely ground products. Outstanding examples of the minerals whose recovery is benefitted by such treatment, include: Florida pebble phosphate (collophanite), garnet, iron oxides, ilmenite, coal, feldspar, spodumene, brookite, rutile, kyanite, corundum, beryl, potash minerals.

Table 1 illustrates the beneficial effect of high solids conditioning in the treatment of a garnet ore.

Table 1 . . . Effect of High Solids Conditioning in Treatment of Garnet Ore

Test Number	Feed, Pct Garnet	Clean Conc., Pct Garnet	Rougher Tail, Pct Garnet	Pct Garnet Recovery in Cleaner Conc.	Pct Solids in Conditioning	Total Time of Conditioning
A	10.0	98.0	0.2	94.2	80	25
B	8.7	97.5	3.5	57.6	22	25
C[a]	8.9	97.6	3.5	43.8	22	25
D	10.7	98.4	0.8	88.3	80	10
E	10.0	54.0	0.2	85.5	22	None
F[b]	10.8	98.4	0.6	90.8	80	25

[a] Pulp aerated during conditioning.
[b] Acid and promoter added together.

Flotation feed was ground to minus 48 mesh and deslimed prior to conditioning.

The benefits of high solids conditioning in the treatment of ilmenite in a slime table tailing were reported in a recent interesting paper[15] by F. R. Milliken, presented at the February 1948 meeting of the AIME in New York. The author states that laboratory testing indicated that improved results were obtainable by greater intensity of agitation, and that in order to obtain this a shearing-type impeller with maximum circulation through the impeller was required for good ilmenite recovery and gangue rejection. This was confirmed to a considerable extent in the plant, after installation of a receded disc impeller and diffuser plate, also a central standpipe to provide maximum circulation in the conditioners. Although laboratory testing had shown no metallurgical benefits from conditioning at higher solids than 40 pct, it was found in the plant that when higher density was tried a further improvement occurred. With the high density conditioning, at about 63 pct solids, it was found that a simple impeller with four radial blades set at 45°, operated to give a downward thrust, gave satisfactory results. These impellers, 24 in. in diameter, operate at 260 rpm in 5 ft diam by 4 ft tanks.

Improved methods for removal of impurities from glass sands, ores, and others, are claimed in T. Earle's U.S. Patents 2,106,887 and 2,106,888 (Feb. 1, 1938). One of the features of these patents involves the preliminary conditioning with reagents and a controlled amount of water "sufficient to satisfy the affinitive capacities of all of the separated particles."

High solids "conditioning" does not appear to be necessary, or even desirable, in the treatment of such nonmetallic minerals as fluorite, calcite (in finely ground cement rocks) rhodocrosite, celestite, gypsum, graphite, talc, when these minerals are finely ground.

Likewise, in the flotation of quartz and certain other silicate minerals using cationic type promoters, it may or may not be advantageous to contact the promoter with the pulp at high solids.

INTENSITY OF TREATMENT

Some pulps require only sufficient time for completion of reaction. Others need, in addition to time, the catalyzing effect of intensity, as noted above.

Some pulps need the minimum of intensity, for example, soft ores which tend to form slimes, also ores which require sulphidization.

The type and intensity of conditioning can have a marked influence on the separating efficiency obtained in the subsequent flotation operations. Hence, it is vitally important in laboratory testing to try to simulate the action

of equipment that is either in use in the plant or which is commercially available.

An interesting example of the importance of intensified conditioning is furnished in an excellent article[16] by Messner and Bein which describes the Big Bend, Calif., operations of Hoefling Brothers. The original conditioners installed in this plant were equipped with 1½ hp motors which proved to be not large enough to permit good aeration. When plant results did not meet those indicated by laboratory testing it was realized that the aeration obtained in the Fagergren laboratory cell was much greater than that in the underpowered conditioners. New 5 hp motors were put on the tanks, the blades on the agitator were steepened to a 40° pitch and the agitators were speeded up to 300 rpm. The tailing losses immediately dropped after these changes. The authors state that increased pulp densities also may have contributed to reduced tailing losses.

At another California operation treating a high pyrite, zinc-lead ore containing 2.7 pct Pb, 9.5 pct Zn (about 3 pct nonsulphide) it was found that increased agitation and aeration during conditioning of the lead tailing resulted in marked improvement in grade of zinc concentrate produced in ensuing flotation operations, as shown by Table 2.

Table 2 . . . Effect of Increased Agitation and Aeration on Ensuing Flotation Operations

Product	Pct Pb	Pct Zn	Pct Zn Recovery	Type of Conditioning
Zinc concentrate	0.5	48–50	±67	Ordinary agitation and poor aeration.
Zinc concentrate	0.5	+60	±67	Vigorous agitation and strong aeration.

The major diluent in both concentrates was pyrite. Less than 2 pct insoluble was present. Increased agitation and aeration improved the rejection of pyrite.

DEGREE OF AERATION

Some pulps, particularly those of heavy sulphide ores, require intense aeration during the pretreatment stage. Certain other pulps do not require aeration and such action may be actually detrimental from the standpoint of increased reagent consumption, lowered flotability, and so on.

In plants where the flotation machines are "sluggish" and give poor aeration, intense aeration of the pulp prior to flotation frequently produces improved results.

The effect of aeration during conditioning has been the subject of a number of technical articles.

O. C. Ralston and his coworkers seem to be among the first to recognize the benefits resulting from adequate aeration during grinding and conditioning prior to flotation of certain types of sulphide ores. Their interesting investigations are reported in a technical paper.[17] Among other things, they concluded that:

. . . grinding of an ore in limewater with exclusion of oxygen, produced a pulp which gave worse results in flotation of chalcopyrite and sphalerite and rejection of pyrite than one in which plenty of oxygen was present during grinding. [Also] . . . the addition of lime to a thick pulp from a grinding mill and conditioning by aerating permitted better subsequent flotation results than adding the same amount of lime to a pulp diluted to flotation density before similar conditioning.

In a written discussion[18] of this paper, C. G. McLachlan, Superintendent of Concentration, Noranda Mines Ltd., reported beneficial results obtained at Noranda, Quebec, by aerating ground flotation pulp prior to flotation in the presence of soda ash rather than lime. This is discussed more extensively in later articles by McLachlan.[19,20]

McLachlan considers that whenever aeration of pulp before flotation is necessary that:

1. Aeration and flotation steps should be carried out separately.

2. Depth of pulp in the conditioner is important if aeration is to be completely effective (more air is entrained in a deep pulp than in a shallow pulp).

3. The aeration step should be completed prior to flotation. One should not have to rely on a flotation machine to provide the remaining aeration that may be necessary if the pulp has not been aerated properly in the conditioner.

At Tennessee Copper Company's operations at Copper Hill, Tenn., J. F. Myers reports* that:

. . . where both pyrrhotite and pyrite are to be depressed with lime, deep aeration conditioning and flotation must be done together. That is the reason we use the deep Munro-Pearse cells on our copper circuit.

Commenting on the action of the Munro-Pearse deep cell, S. R. Zimmerley of the Salt Lake Station, U.S. Bureau of Mines states* that:

. . . an analysis of where pretreatment or conditioning leaves off and flotation begins might be pertinent. For example, in the deep cell air is introduced many feet below the surface of the pulp, whereas in Booth's new machine flotation is accomplished on introducing the air only a few inches below the surface. Apparently the deep cell also functions as a sort of dynamic conditioner. The individual mineral surfaces may be undergoing a change (involving some complex oxidation reaction perhaps) from unfavorable to optimum back to unfavorable conditions for flotation and when the most favorable condition exists for the individual mineral particles it floats and is removed from the system. If differently sized particles react at different rates, then any static or bulk system of conditioning would result in over-conditioning of some grains and under-conditioning of others. Deep cell flotation then would represent another fundamental type of conditioning.

Aeration of pulp in a conditioner prior to flotation was practiced in the treatment of the chalcopyrite-pyrrhotite ore milled by Consolidated Copper and Sulphur Co. at Eustis, Quebec. Milling practice at this old property which has subsequently been shut down, is reported in a paper[21] by Baxter and Snow.

As an interesting sidelight on this subject of aeration of pulps during conditioning, it is to be noted that, at one plant at least, improved results are reported to have been obtained by aerating the milling water. An article[22] by Owen Mathews, describes the benefits of this method of treatment in the flotation plant of Cochenour Willans Gold Mines Ltd. in the Red Lake area of Northwestern Ontario.

TEMPERATURE

Flotation results are usually improved when operations are conducted at elevated temperatures. This is particularly true when treating minerals of poor flotability such as marmatite. Also, the flotability of most nonmetallic minerals is considerably poorer in cold water than in warm water when soap-type promoters are used. Under certain

* Personal communication.

* Personal communication.

favorable conditions, particularly where it is possible to pretreat pulps at high solids it may be a paying proposition to heat the water used for the pretreatment step. The costs for such treatment may be offset by reduction in reagent requirements, reduced amount of equipment for pretreatment and flotation, or better overall metallurgical results. Heating of reagents before adding to mill pulps is also reported by J. J. Burns, to be beneficial at the Balmat, New York, mill of St. Joseph Lead Co.

In the early days of flotation, heat was commonly used in the conditioning stage ahead of flotation of zinc sulphides. Currently, few plants employ this aid. Those that do maintain that the benefits of heat cannot be realized by substituting reagents, time, or intensity of "conditioning." Heat seems to be particularly valuable, especially in wintertime operation when treating martite ores. Copper ammonium sulphate is reported by D. M. Kentro to give better results than copper sulphate and has replaced heating of pulps at the Shenandoah Dives mill in Colorado.

Some nonmetallic operations report benefits from heating of pulps prior to flotation. The selective flotation of fluorspar from other easy floaters such as calcite is aided partly because less promoter (oleic acid) is required in warm pulps compared with cold pulps.

Wark and Cox have made laboratory studies of the influence of temperature on adsorption of xanthate at surfaces of certain pure sulphide minerals—galena, pyrite, arsenopyrite, chalcopyrite and sphalerite, and on the effects of alkali, cyanide and copper sulphate in hindering or promoting the adsorption. Their conclusions as expressed in their paper[23] are as follows:

1. In the absence of copper sulphate, a change in temperature from 10 to 35°C merely alters slightly the amounts of depressants (cyanide and/or alkali) necessary to prevent contact, a greater concentration of depressant being necessary to prevent contact at 10° than at 35°C.

2. In the presence of copper sulphate, the influence of temperature on the amounts of cyanide and/or alkali necessary to prevent contact is slight for chalcopyrite and sphalerite, but is relatively great for pyrite and arsenopyrite. Under these conditions, pyrite and arsenopyrite are much less influenced by the depressants at 35° than at 10°C.

3. The conditions most favorable for floating sphalerite away from pyrite are low temperature, low xanthate concentration, and if low temperature is impractical, a small range of pH values which for the conditions used here is between 6 and 8.

4. The conditions most favorable for floating chalcopyrite or other copper-bearing sulphide minerals away from pyrite are likewise low temperature and low xanthate concentration.

5. There appears to be little advantage in raising the temperature of the system above 35°C when pyrite or arsenopyrite is to be floated in the presence of copper sulphate and sodium cyanide.

6. The differentiation between sphalerite and pyrite when using amyl xanthate in a circuit containing copper sulphate and cyanide is much diminished as the temperature is raised.

It is to be noted that certain of these conclusions would appear to be at variance with results obtained in practical operating practice.

While on the subject of temperature, mention should be made of the utilization of steaming of pulps of copper sulphide-molybdenite concentrates, to destroy the promoters and permit superficial oxidation of the copper sulphides preparatory to selective flotation of molybdenite.

The use of high temperature conditioning (above 35°C and preferably above 60°C) in connection with the soap flotation of nonsulphide ores, as covered in B. Kalinowski's French Patent No. 847,215, Dec. 7, 1938, is claimed to provide more intensive activation, better separation of values from gangue, and reduction in quantity of reagents.

It is reported that at one of the fluorspar flotation operations in this country enhanced results are obtained when the flotation feed is conditioned at boiling temperature for a period of 15 to 20 min prior to flotation without cooling the pulp.

METHOD AND ORDER OF ADDITION OF REAGENTS

In general the desirable sequence of addition of reagents seems to be:

1. Regulating agents—lime, soda ash, acid, and others.
2. Activating or depressing agents.
3. Promoters and frothers.

Although the above generalization will apply to many ores, there is no universal acceptance among millmen as to the proper sequence of reagent additions. One can usually start an argument at any meeting of practical operators on such controversial points as the following—to name a few:

1. Addition of lime before or after copper sulphate for zinc sulphide flotation. Also the employment of alkalinity regulators before or after addition of activators for other minerals.

2. Addition of depressants before or after addition of alkalinity or acidity regulators.

3. The benefits obtainable when promoters are added together with, prior to, or following, the addition of depressants, activators, or regulating agents.

4. Whether some reagents can be most effectively used when dispersed, solubilized, diluted, or mixed with the mill water before being added to the pretreatment apparatus. For example, the addition of emulsified fatty acids to mill water, cation reagent to mill water, or dilution of concentrated sulphuric acid before adding to pulp.

In general, it is usually desirable to try to complete one reaction with one reagent before another reagent is added. Reagents should not have to compete with one another, at the expense of reacting with mineral surfaces.

F. W. McQuiston, Jr., notes* that the unorthodox practice of adding copper sulphate and xanthate in stream contact with each other for zinc sulphide activation and promotion has been found to be the most effective method of reagent addition used to date at an important western mining operation. He adds that the copper-xanthate precipitate formed is a potent sphalerite promoter.

An example of the importance of proper sequence of reagent addition is to be found in the treatment of complex copper-zinc ores of California where the order of reagent addition in conditioning ahead of flotation has a marked influence on selectivity and recovery of values.

The following practice is reported to yield best results on ores containing the copper minerals chalcopyrite, chalcocite, covelite and bornite; and sphalerite and pyrite; with gangue minerals, comprising quartz, chlorite, sericite, amphibole, and barite.

Copper Recovery

1. In the grinding circuit, excess alkalinity is avoided, and the pH kept at about neutral or below 7.3. Sodium

* Personal communication.

sulphite is added to the ball mill as an auxiliary depressant for sphalerite and pyrite.

2. To the conditioner ahead of flotation, cyanide is added as a zinc depressant, together with a small amount of an auxiliary promoter for copper sulphides.

3. To the flotation circuit a small amount of the principal promoter and a frother are added to assist recovery of the copper sulphides.

4. The rougher concentrate is cleaned after conditioning it with cyanide and zinc sulphate. The cleaner tailing is returned to the grinding circuit.

Zinc Recovery

The tailing from the copper roughing circuit is treated as follows:

1. To the primary conditioner copper sulphate and a suitable promoter are added. It is important to avoid alkalinity at this stage and the pH of the pulp is about 6 to 7.

2. To the secondary conditioner lime is added to give an alkalinity corresponding to 0.5 to 1.0 lb CaO per ton of solution.

3. Following this two-stage conditioning an auxiliary promoter and frother are added and a zinc concentrate is recovered.

4. The zinc rougher concentrate is cleaned and the cleaner tailing returned to the primary conditioner.

General Notes in Connection with the Above

Proper alkalinity at the right time and at the right place, plus the right order of addition of copper sulphate and lime to the conditioners are all key factors in securing optimum results. Good aeration during conditioning is also helpful in securing selective flotation. The double conditioning in the zinc circuit is especially valuable in wintertime operation when low pulp temperatures obtain.

In the flotation of some oxidized lead ores, a combination of sodium sulphide and copper sulphate yields better results than sodium sulphide alone. When these reagents are used, the order of addition is important. The sulphidizing agent is added to the pulp first and conditioned with it for only a short period—3 to 4 min—and then copper sulphate is added in a separate conditioner to complete the activation and neutralize excess causticity due to the sodium sulphide. Finally, the promoter agent and frother are added to the conditioned feed just ahead of the flotation machines.

A. F. Taggart notes[24] that "Unlike sulfides, the nonmetallic minerals will not, in general, float well without the presence of an insoluble coating oil in the pulp." For this purpose he states that petroleums are generally used and that the sequence of steps in oiling are first, reaction between the organic acid radical of the collector and the mineral, to form a water-insoluble coating compound and thereafter oil-coating of the altered surface. He states that:

> Addition of the collector agent in solution in the insoluble oil has the further advantage that it holds back saponification of the fatty or resin acid and thus introduces the organic acid radical in ionized form and at a rate, substantially, no faster than the mineral can consume it. There is thus, little wastage of the fatty acid, and the evil effects of excess soluble soap (overfrothing) are avoided.

The *place* at which reagents are added, as well as the order of their addition can have an important bearing on the efficiency of separation in the subsequent flotation step. In this connection, certain experiments by Gaudin and Malozemoff on sulphide minerals of near-colloidal size, results of which are reported in a technical paper,[25] lead these investigators to postulate two principal reasons for the poor flotation of minerals of near colloidal size. In brief, sulphide minerals with "young" surfaces do not float readily, for mechanical reasons, that is, low probability of contact of the particles with bubbles, and sulphide minerals with "old" surfaces do not float readily because they have had their surfaces exposed for a long time to the action of salts in the pulp so that their surfaces become coated with an inert compound. Since, owing to their size, they do not become ground while the coarse particles of ore go through the grinding steps, their behavior in flotation is subnormal. However, experiments by these investigators indicate that the formation of these coatings can be completely prevented by the addition of the collector into the grinding machine so that the collector shall be present in the grinding system while the mineral particles are being broken and expose their fresh surfaces. In this way, the authors claim, the collector is permitted to cover the surface of the mineral first and thus protect it against other agencies in the system. These latter conclusions seem to be at variance with the postulation that because of their fine size the particles with old surfaces do not become ground, and it would appear that there is no reason why they should be affected by the promoter added to the grinding circuit. It is quite conceivable however, that in the case of freshly-ground sulphides of near colloidal size it would be advantageous to have promoter available for reaction as soon as the fresh surface is exposed, thus preventing reaction between the fresh surface and soluble salts in the pulp. However, it would also appear that the addition of promoter to the grinding circuit would not be justified if two sulphides of near flotability were required to be separated in a subsequent flotation step. In the latter case, the presence of the promoter might nullify the effect of the depressant, or depressants, which was added to insure selective flotation.

Apparatus Used for Pretreatment of Mineral Surfaces

It is beyond the scope of this paper to describe in detail the various types of equipment that are in use, or which might be employed, for the pretreatment of mineral surfaces ahead of flotation. However some brief remarks on this subject may be of interest.

As regards scrubbers, and attrition mills, passing reference has already been made in this paper to certain types which provide for more intense cleaning of mineral surfaces than the better-known forms of disintegration apparatus such as the drum scrubber, blade mill, log washer, sand screw washer, trommel washer, and the like.

The purposes of "conditioning" apparatus have already been stated. The type and size of these units will depend upon the functions which they are called upon to perform.

For simple conditioning of finely ground pulps at relatively low solids (20 to 50 pct) a round tank provided with means for positive circulation of pulp at sufficient velocity to prevent sedimentation of solids, may be used.

When finely ground pulps are to be handled at high solids or where more intensive agitation and aeration of pulps is required, round tank-type conditioners may be used—but special type agitators, such as turbine-bladed impellers, operating at relatively high speed are desirable.

In cases where intense aeration is

essential, the special type of aerator developed at Noranda Mines Ltd. may be required. A description of this apparatus is given by Taggart.[25] It comprises a circular tank about 9 by 15 ft with four rubber air-lift pipes, a plurality of radial air-inlet pipes of different inward extension, and a slow-moving under-driven rake mechanism at the bottom.

For the treatment of coarse, relatively slime-free pulps, and fast-settling pulps of heavy minerals, at high percentage of solids, it is common practice to use a multiple of shallow cells. For example, for the precoiling of relatively coarse, deslimed phosphate flotation feed at 69 to 70 pct solids, the apparatus used at one plant comprises a four-cell unit, each cell 43 by 43 in., with provision for an effective pulp depth of 22 in. Cruciform impellers used for mixing are 18 in. diam with 4 in. face, and turn at 160 rpm. Actual power consumption in the operation of these impellers amounts to 10 hp per cell. At another nonmetallic operation, three 31 by 31 in. cells, providing an effective pulp depth of 24 in., are used to precoil at 67 pct solids a coarsely ground deslimed ore of about 2.8 sp gr. The rubber-covered propeller-type agitator, 12 in. diam, is run at 235 rpm, and in a direction to provide a down thrust to the pulp. Power consumption amounts to 7½ hp per cell.

At still another nonmetallic operation, a minus 35 mesh, deslimed ore of relatively high specific gravity—3.2—is "conditioned" at approximately 80 pct solids in two 4 ft diam by 3½ ft depth wooden tanks equipped with 24 in. diam turbine-blade type agitators. The latter are driven at 163 rpm. Power consumption amounts to 7½ hp per unit.

Drum-type mixers, revolving on trunnions, and equipped with lifter blades are also very effective for mixing coarse, deslimed phosphate flotation feed at high solids with reagents.

Summary

This important phase of the flotation process—pretreatment of mineral surfaces—warrants more attention than it sometimes receives; since it offers opportunities for improved metallurgical results as well as savings in reagents and flotation machines. Laboratory control tests on mill pulps should conform to the flowsheet and type of apparatus used in the plant for pretreatment or "conditioning." In laboratory studies close attention should be paid to the variables involved in pretreatment of mineral surfaces. Flowsheets and apparatus recommendations for commercial operation based on such studies should conform to the particular procedures and techniques developed in the laboratory, in order to ensure maximum dollar return at minimum cost.

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26. Sec. 12, p. 33 of ref. 1.

Open Fracture in Langbeinite, International Minerals and Chemical Corporation's Potash Mine, Eddy County, New Mexico

By JAMES B. CATHCART,* Junior Member AIME

The potash mine of the International Minerals and Chemical Corp. is about 18 miles east of Carlsbad, New Mexico, in sec 1 and 12, T 22 S, R 29 E, N.M.P.M. Potash is produced from two zones in the Salado formation of late Permian age. The lower zone, consisting of a mixture of sylvite (KCl) and halite (NaCl), lies at a depth of about 900 ft, and the upper zone, in which the principal potassium mineral is langbeinite ($K_2SO_4 \cdot 2MgSO_4$), lies at a depth of about 800 ft. Because of the plastic nature of the material, fractures in the Salado formation are extremely rare and have been noted only on the 800 ft level of the International mine. The open fracture described below is almost unique. Only one other open fracture has been noted, and it was on a working face in the same general area as the one described, but was destroyed before the writer had a chance to examine it. According to J. E. Tong, foreman on the 800 level, this fracture was similar to, but smaller than, the one herein described.

The saline strata are nearly flat-lying and comprise interbedded layers of halite, anhydrite ($CaSO_4$), and polyhalite ($2CaSO_4 \cdot MgSO_4 \cdot K_2SO_4 \cdot 2H_2O$), with halite predominating. The halite layers contain local concentrations of sylvite, carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), and langbeinite. The principal marker in the potash mines area is a bed of anhydrite about 8 ft thick, and 70 ft below the 800 level. This bed contains varying amounts of polyhalite, and locally a few blebs of sylvite.

Two principal marker beds are present over most of the 800 level. The lower is the "Middle Salt Marker," a bed of bright-orange halite, which ranges in thickness from a knife-edge to about 0.6 ft, and is usually bounded above and below by thin seams of green or reddish-brown clay. In langbeinite-rich areas, this marker usually contains abundant blebs of langbeinite. The upper of the two principal markers is a green clay seam, containing abundant halite, which ranges in thickness from 0.1 to about 0.5 ft. It is 2 to slightly more than 5 ft above the Middle Salt Marker. No langbeinite of minable grade is found above this clay, and it

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*Geologist, and Project Chief, U.S. Geological Survey, Plant City, Fla.

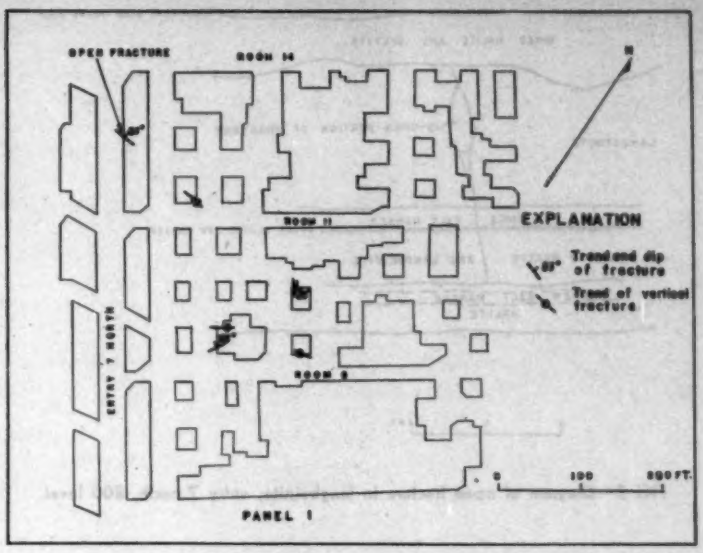

FIG 1—Plan map of a portion of the 800 level. (Base from Company map, April 1947.)

forms a comparatively even roof, so in the ordinary course of mining the salts are broken to this clay seam. A third, but less prominent marker, the "Lower Salt Marker," is also present on this level. It is a bed of orange halite, but is indistinct, and it is not present, or at least not recognizable, over much of the level. Where it can be recognized, it is about 2 ft below the Middle Salt Marker.

The open fracture in the langbeinite is found on the east wall of entry 7 north, between rooms 11 and 14 (Fig 1). The fracture strikes N 85°E and dips 85° north. The opening along the fracture extends 2 ft vertically, is 0.7 ft in maximum width, and extends at least 2.5 ft into the barrier pillar. About 1 ft back of the face of the pillar, the width of the opening is less than 0.1 ft. It is probable that the actual maximum width is somewhat less than the 0.7 ft, because the opening has been enlarged by blasting and subsequent chipping. Nothing is known of the former extent of the opening into the area now occupied by the entry. The fracture does not extend across the entry, however, as no trace of it can be found on the pillar on the opposite side of the entry. The open part of the fracture is confined to the highest grade langbeinite, and pinches down to a knife edge above and below. Above the langbeinite is a mixture of sylvite and halite, and the fracture stops abruptly at the contact. Below the opening, the fracture can be traced down through the Middle Salt Marker, which is here chiefly langbeinite, to the lower contact of langbeinite and halite, where it is sharply cut off.

The sharp termination of the fracture at the contact of the langbeinite with mixed sylvite and halite above, and with halite below is particularly striking (Fig 2). Langbeinite has a hardness (Mohs scale) of 3 to 4, whereas the hardness of halite is 2.5 and that of sylvite is only 2. Langbeinite is apparently the only mineral hard enough and competent enough to maintain an opening. Halite and sylvite may have been competent enough to fracture, but if so the weight of the overlying beds has caused these salts to flow slightly, healing the fracture. It is interesting to note that the fracture is sharpest and clearest in the best grade of langbeinite; that is, where there is least halite in the langbeinite. In the langbeinite below the Middle Salt Marker there is a large proportion of halite, and the fracture can be traced only with difficulty. The fracture does not extend to the opposite side of the barrier pillar, probably because the opposite side of the pillar consists almost entirely of halite, not competent enough to fracture.

Evidence that solutions passed through the fracture is lacking. The edges of the fracture are sharp and clear, and there is no evidence of solution or erosion of the wall rock. A very thin film, composed of a very fine-grained to microcrystalline white mineral, picromerite, a hydrate of langbeinite with the composition $K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$, is present on the walls of the opening, and as a filling where the fracture narrows down. This mineral may have been precipitated from connate brine squeezed from the enclosing salts.

Evidence that this is a true fracture and not a crack caused by blasting can be summarized as follows:

1. The fracture is continuous through the langbeinite; blasting cracks usually extend only about a foot from the drill hole.

2. Openings along blasting cracks are narrow, none are more than a fraction of an inch wide, and none are very deep.

3. No coating of hydrate is found in the cracks produced by blasting.

4. Blasting cracks are normally confined to the corners or edges of pillars;

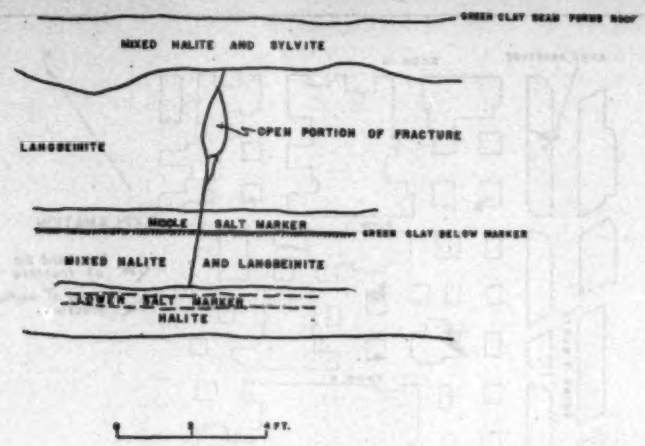

FIG 2—Diagram of open fracture in langbeinite, entry 7 north, 800 level.

this fracture is almost in the center of a pillar.

5. Blasting cracks are most numerous at the end of a round, that is, the bottom of the drill hole; this fracture is in the approximate center of a round.

Several other fractures are shown on the map (Fig 1). None of these fractures are open, but they are similar to the open fracture in that they occur in bodies of langbeinite, terminate at the top and bottom of the langbeinite, and have a thin film of picromerite on the fracture face. Thus, they are believed to be true fractures rather than blasting cracks. Probably more fractures are present than are shown, but those that are not open are difficult to distinguish from blasting cracks, and any that were of doubtful origin were omitted from the map.

Possible Origin

A slight regional tilt to the southeast, and superimposed broad, gentle, northwest-trending folds are the major structural features in the vicinity of the International mine. The fractures in the langbeinite bodies are possibly due to the same compressive stresses that caused the gentle folds.

Practical Aspects

It is of interest to note that heretofore it has been generally assumed that because of the plasticity of salt and sylvite there would be no fractures through which water and gas could enter the mine. The recognition that fractures do occur in the "salt" section is important in that it should influence the approach to such matters as the plugging of drill holes and other mining problems involving the exclusion of water from the salt.

It is of interest to note here that after this paper was written, a long entry of the Potash Company of America penetrated a crack through which oil was seeping. This exposure was not seen by the writer, but it serves to illustrate the importance of the fracturing in the "salt" section.

Salt Resources of West Virginia

By PAUL H. PRICE,* Member AIME, and JOHN P. NOLTING*

History

The history of the salt industry in West Virginia dates back nearly two hundred years; however, the history of salt as an important raw material for the chemical industry is much more recent.

The earliest record of West Virginia salt was in 1753, when a raiding party of Shawnee Indians attacked frontier settlements in Virginia taking captive a number of the pioneers. One of these, who later escaped and returned to her friends, described how the Indians camped at a salt spring on the banks of the Kanawha River and evaporated the water to obtain a supply of salt to take back to Ohio with them.

Settlement of the Kanawha Valley began in 1774, that same year the Battle of Point Pleasant ended the Indian's power in the Ohio Valley; and settlement of the Kanawha Valley progressed rapidly with a consequent increase in the importance of the Kanawha Licks as a source of salt. In those days the evaporation of the brine was a family matter for which the family wash-kettle was commandeered.

In 1797, Elisha Brooks erected the first salt furnace in the Kanawha Valley. It consisted of two dozen small kettles set in a double row, with a flue beneath, a chimney at one end, and a fire bed at the other. He obtained his brine at a depth of 20 to 30 ft by sinking hollow logs, called "gums" into the salt lick and dipping the brine with a bucket. His production was about 150 lb a day and sold for 8 to 10 cents a pound.

In 1806, the Ruffner brothers, David and Joseph, prospected for and drilled the first well in America using a spring pole and steel chisel bit. After several failures they succeeded, in 1808, in drilling to a total depth of 59 ft where they secured a good flow of strong brine. Most standard drilling tools, jars, casing, and practically all the basic oil well drilling machinery now in use, were developed in the drilling of salt wells. To evaporate this brine, the brothers built a wood-burning furnace similar to that of Brooks but with a better arrangement and with more and larger kettles. When production was started they reduced the price of salt to 4 cents a pound.

By 1817, there were some 30 salt furnaces in the Kanawha area. It was in this year that bituminous coal first was used as an industrial fuel. David Ruffner again pioneered the way by converting his furnace for the consumption of coal. This year also brought about the formation of the first trust which controlled production and set a price of 1 cent a pound for the salt.

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Table 1 . . . Summary of Averages of Chemical Analyses of Brines of West Virginia for Four Major Horizons, in Parts per Million[1]

Geological Horizon	Number of Samples in Average	Temperature °C	Density	Solids after Evaporation	Fe	Ca	Sr	Ba	Mg	Na	K	HCO_3	SO_4	Cl	Br	I	Total Determined Constituents
Salt	106	25.1	1.0221	60,089	215	4,284	128	316	888	16,840	167	279	23	36,401	210	2.33	59,380
Maxton	19	25.4	1.0597	87,642	42	6,274	168	679	1,459	24,063	204	132.3	7.9	52,934	318	3.7	86,288
Big Injun	33	25.6	1.0697	99,845	155	7,722	204	193	1,685	26,994	320	129	41	60,704	458	6.8	98,532
Oriskany	6	23.3	1.1936	252,717	60	17,615	1,010	32	2,606	72,317	2,777	127	342	152,870	1,135	11	250,736

[1] References are at the end of the paper.

In 1833, George H. Patrick invented the multiple effect evaporator. In this system the brine from the wells was first pumped to a reservoir, and the desired amount allowed to flow to the pan where it was concentrated almost to the saturation point. It then flowed to settling vats where the muddy material and iron salts settled out. After this the purified salt solution flowed to the "grainer" vat for further evaporation resulting in the finished product. Salt then sold for ¼ cent a pound.

The use of gas as a fuel for the salt industry was brought about by accident. In 1841, William Tompkins, in boring a salt well near Washington Spring, struck a large flow of gas which he used as fuel for his furnace thus making a great saving in fuel and lowering the cost of production.

The period of maximum production of the Kanawha Valley salt industry occurred between 1845 and 1854, beginning with road improvements and ending with competition from Ohio Valley producers which further cut the price to ¼ cent a pound. The peak year was 1846, during which 3¼ million bushels, or 80,620 short tons, of salt were produced. By 1875, the ten existing salt furnaces had a capacity of about two and one-half million bushels but because of the competitive market less than one million bushels were produced.

During the time of the rise of the Kanawha salt industry minor salt developments took place in other West Virginia counties, but all of these were secondary in importance to the Kanawha industry.

The most important of the other salt developments was that in Mason County. This development was started at West Columbia in 1847, by three former Kanawha salt makers. The brines in this area were denser than the Kanawha brines and the area had the added advantage of better river communication with the West. By 1876, Mason County had a capacity of 75,000 tons of salt a year.

Salt was also produced in small quantities from wells scattered throughout the rest of the state. The production from these wells was so small that most of them deserve no more than passing mention. However, one well drilled near Sago, Upshur County, is of interest in that some years before the beginning of the oil industry, when the owner tried to deepen his well to increase production, he struck oil, and had to abandon the well because the unwanted oil ruined his salt production.

Despite the decrease in the importance of the Kanawha salt industry after 1854, some men recognized the possibility of using salt brine as a raw material for chemical products, as early as 1876. This did not materialize however, in West Virginia, until the early days of World War I.

In 1914, the Warner-Klipstein Chemical Co. erected a plant in South Charleston to produce chlorine and caustic soda from brine. This plant is now the Westvaco Chlorine Products Corp., the largest chlorine production plant in the world.

Between 1913 and the end of the war, many other chemical companies constructed plants to use salt brine as a raw material for the manufacture of chemical products.

Since that time the chemical industry, based largely on the use of salt brine, has experienced a tremendous growth in the Kanawha Valley.

Although, for many years, rock salt was believed to be present under the northern part of the state, it was not until the Second World War that the rock salt industry had its beginning in West Virginia. In 1942, the Defense Plant Corp. built an electrolytic caustic soda plant at Natrium, in Marshall County, where the rock salt is extracted by water solution from drilled wells. This plant is owned and operated now by the Columbia Chemicals Division of Pittsburgh Plate Glass Co.

Sources and Origin of Salt Brine

Salt occurs in two major forms in West Virginia, first as a salt brine and second as rock salt. Salt brine may be thought of as connate, or entrapped sea water.

As marine sedimentation took place solid material such as clay, silt, or sand particles, settled in standing bodies of water to form unconsolidated sediments, the pore spaces of which were filled with salt water. As the beds became thicker and compaction took place, some of this pore water was squeezed out and some remained in the more porous beds. As cementation occurred part of the original sea water was trapped in the pore spaces. In some cases, later land movements elevated these water-bearing rocks above sea level, erosion exposed the brine-bearing horizons permitting the entrance of surface waters which resulted in the dilution of the contained brines. In other cases, gas associated with brine-bearing rocks caused the evaporation of part of the water resulting in concentration of the brine.

Beside the dilution and concentration of brines, temperature and pressure changes, and contact with rocks, gases and other waters may all have had an effect upon their present composition.

In studies of the salt brines of West Virginia, carried on by the West Virginia Geological Survey in 1937 and 1947, brine samples were obtained from 21 different horizons in 38 counties of the state, and in adjacent parts of neighboring states. These horizons range in geologic age from the Moundsville Sand (Saltsburg) of the Conemaugh to the White Medina (Clinton of Ohio) of the Silurian. Complete chemical analyses of 308 samples have been made. A study of the producing horizons leads to the conclusion that the concentration of the brine increases with geologic age. The heaviest Salt

Sand brine taken from a well had a specific gravity of 1.1243; the heaviest Big Lime brine was 1.1299; the heaviest Big Injun brine was 1.1449; that for the Brown Shale, 1.1617; and the heaviest Oriskany was 1.2246. The brines from the lower horizons seem to be very nearly saturated with calcium chloride. Brines obtained from the anhydrite-gypsum zones of the Silurian are generally impregnated with hydrogen sulphide. The reserves of the four largest producing horizons, the Salt Sand, Maxton, Big Injun, and Oriskany, have been calculated as totaling nearly 800 million tons of salt.

The Salt Sands ordinarily contain the larger volumes of brine; the brine from the Big Injun is generally of greater density but the volumes are usually smaller.

Table 1 gives a summary of the average chemical analysis of the brines of the four major producing horizons.

Geologic Occurrence of Salt Brines

As brines are considered to be connate water, the search for them should be confined to marine sediments. The upper half of the Conemaugh and all of the Monongahela Series of the Pennsylvanian System and Dunkard Series of the Permian System are of continental or nonmarine origin. The youngest known marine formation in West Virginia is the Ames limestone which occurs in the middle of the Conemaugh Series, or about 300 ft below the well-known Pittsburgh Coal; hence the commercial occurrence of salt brines would not be expected above this horizon.

PENNSYLVANIAN SYSTEM

The Conemaugh Series

The lower half of the Conemaugh Series contains three brine-bearing horizons; however, they are relatively shallow and not of commercial importance.

The Allegheny Series

Although the Allegheny Series has several massive sandstones they are not important brine-bearing formations.

The Pottsville Series

The Pottsville Series contains several massive sandstones which produce brine throughout the oil and gas fields of the state. These horizons are referred to by the drillers as the "Salt Sands" and may be numbered according to their position in the rock column. Due to their widespread occurrence and porous texture they offer great commercial possibilities for brine production. It was this group of sands which made possible the development of the early salt industry in the Kanawha Valley.

MISSISSIPPIAN SYSTEM

The Mauch Chunk Series

This series, which is composed of red shales and thin sandstones in the northern part of the state, thickens to the south with a considerable increase in the amount of sandstone present. The lower part of the series, having more marine sediments, includes the Maxton sand which contains brine in northern West Virginia.

The Greenbrier Series

This series is predominantly marine limestone but produces some oil and gas, and brine has been reported from "Big Lime" wells in a few localities.

The Maccrady Series

This series consists essentially of red shales and is usually thin or absent in the oil and gas regions of the state. While it is not an important brine producer in West Virginia, it is the source of the salt produced at Saltville, Va.

The Pocono Series

The Pocono Series contains marine sandstones and shales. Among the several oil and gas sands which it contains, the "Big Injun" is the most important from the standpoint of both petroleum and brine. The "Big Injun" contains large quantities of very concentrated brine in some parts of the state.

DEVONIAN SYSTEM

The Oriskany Series is the only member of the Devonian which is an important brine horizon. It is definitely of marine origin and the brine from this series is much more concentrated than the brines from the younger formations.

SILURIAN SYSTEM

Although some few samples of brine have been obtained from Silurian rocks, these rocks are not considered as important brine bearers. The importance of this system from the viewpoint of salt lies in the rock salt deposits of the Salina Group.

Rock Salt

Records of wells drilled in western Pennsylvania and eastern Ohio indicated that the Silurian salt beds, long worked in New York, would be present under our northern panhandle. Columbian Carbon Company's Lewis Maxwell well in Doddridge County, was the first to show conclusively that such deposits actually existed. Since then several more wells have shown its presence; however, the great depth of the salt has retarded its commercial development. Where the salt is now recovered from mines and wells in New York State, it is less than 1500 ft below the surface; at Cleveland, Ohio, 2400 ft, and at Barberton, Ohio, 2800 ft. The shallowest depth in West Virginia is nearly 5000 ft.

The rock salt deposits of West Virginia and the associated dolomites, anhydrites, and limestones are stratigraphically equivalent to the Salina Group of New York and to the Wills Creek or Roundout limestone of the eastern counties of West Virginia. Part of the salt is probably of the same age as the Tonolaway or Boesardsville limestone of the eastern outcrops.

Except where the salt is actually mined as in New York and Michigan, our knowledge of the salt is based on drill cuttings and cores.

In drilling wells with rotary equipment, salt does not appear ordinarily in the cuttings from these great depths because it is dissolved in the drilling muds.

Anhydrite, the anhydrous calcium sulphate, is much less soluble in water than salt and less concentration of sea water is required for its precipitation. Hence, where bedded salt deposits occur, anhydrite is distributed more widely than salt. In the Appalachian region the driller is likely to record the occurrence of anhydrite as "lime," thus it may occur in many wells where its presence has not been recorded.

CHEMICAL COMPOSITION

The chemical composition of rock salt from three different localities in the state is essentially the same in so far as the soluble salts are concerned,

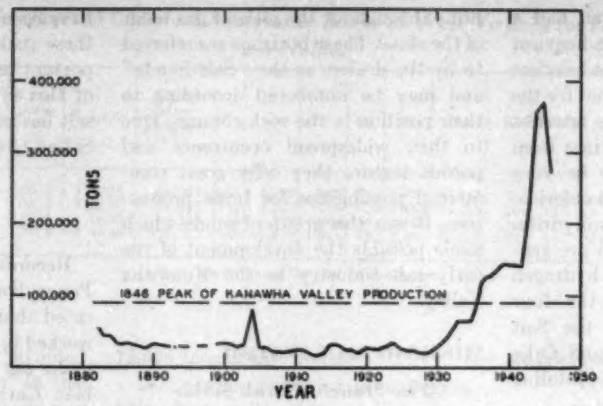

FIG 1—Salt production in West Virginia.

the chief difference being in the insoluble residues. While the brine from the solution of rock salt would need treatment before using, the amount of impurities is comparatively small. Sodium chloride is much higher in percentage in rock salt than in natural brines and calcium and magnesium salts are quite low. Bromine and iodine are trace elements, and barium is generally absent.

ORIGIN OF ROCK SALT

Nothing gained from our knowledge of rock salt deposits in West Virginia throws any further light on the existing theories of origin. There can be no doubt that the Silurian salt deposits of New York, Pennsylvania, Michigan, Ohio, and West Virginia were formed in the same general way, even though conditions varied in some detail in the various states.

It is generally agreed that bedded deposits of rock salt were formed by evaporation of salt water, where desert conditions prevailed; and there could have been no appreciable amount of fresh water flowing into the salt-water body.

Probably the most comprehensive work ever done on the subject was by H. L. Alling,[2] who, after due consideration of many theories of origin, came to the conclusion that: "The salt must have originated by evaporation under desert conditions behind a bar or barrier separating the basin or basins from the sea." The amount of salt in the sea water entrapped in the basin could not be sufficient to produce such thicknesses of rock salt as are known to occur; it is necessary then to consider a bar or barrier between the basin and the sea, low enough to allow the influx of additional sea water into the basin, but shallow enough to prohibit the outflow of the denser basin water to the sea.

The evaporation of the sea water resulted in the differential deposition of the various salts. As evaporation proceeded and the sea water was reduced to about 11 pct of its original volume only iron, calcium carbonate, and gypsum were deposited. As the volume decreased from 11 to about 1.5 pct, sodium chloride was precipitated along with small amounts of gypsum, magnesium sulphate and chloride, and sodium bromide. The "mother liquor," namely, the sea water less than 1.5 pct of the original volume, contained the remainder of the sodium chloride and most of the magnesium sulphate and chloride, sodium bromide and potassium chloride. This differential deposition coupled with the influx of additional sea water, resulted in the formation of large deposits of fairly pure sodium chloride. The reason for the nondeposition of the salts remaining in the "mother liquor" is probably that these dense solutions finally reached the level of the barrier and flowed out into the sea.

The anhydrite layers both above and below the salt beds are also chemical precipitates. This is probably also true of the limestones and dolomites associated with the salt.

Table 2 furnishes estimates on depths to salt in the northern part of the state.

AREAL EXTENT AND RESERVES

The area of rock salt deposits in West Virginia and nearby states, shown by wells in which salt is known to be present includes all or a considerable part of Hancock, Brooke, Ohio, Marshall, Wetzel, Tyler, Pleas-

Table 2 . . . Depths to Salt in West Virginia[3]

Locality	Surface Elevation	Estimated Depths to Salt
Chester, Hancock County	700	4,875
Westernmost part of Hancock County, near Ohio River, opposite Yellow Creek	700	4,820
Wellsburg, Brooke County	680	5,940
Wheeling, Ohio County	700	6,355
Greer, Monongalia County	1,460	8,400
Morgantown, Monongalia County	850	9,100
Fairmont, Marion County	900	9,200
Bens Run, Tyler County	640	6,300
Belmont, Pleasants County	640	5,700
Natrium, Marshall County	689	6,724 (actual depth)
2 mi. southwest of Goose Creek, Ritchie County	830	6,523 (actual depth)
Near West Union, Doddridge County	1,138	7,758 (actual depth)
Near Lost Creek, Harrison County	1,113	8,036 (actual depth)

ants, Monongalia, Marion, Harrison, Doddridge and Ritchie counties. The amount of information on thickness of rock salt in West Virginia is meager. While the bed has a thickness of 110 ft in Marshall County, a well in a nearby Ohio County suggests that there may be another bed in West Virginia below the one already penetrated.

Rock salt has a specific gravity of 2.17 and weighs about 135 lb per cu ft. A salt bed with an average thickness of 100 ft, would yield 188 million tons per square mile. Since there are, in West Virginia, at least 2400 square miles underlain by rock salt, it is seen that the total reserves are enormous.

Although its presence has not been shown, there is reason for believing that rock salt may be found in the Silurian rocks of our northeastern counties (Hampshire, Mineral, and Morgan) where the geologic conditions are favorable. This belief is based upon the occurrence of imprints of salt crystals in the Wills Creek and Tonoloway formations and the report years ago of the existence of strong salt springs in the Keyser area.

Salt Production and Use

From the beginning of the salt industry until 1942, all of the salt produced in West Virginia was derived from salt brines, after 1942 production consisted of both brine and rock salt. Fig 1 shows the general trend of salt production in the state as compared with production during the peak year of the early industry in the Kanawha Valley. From 1882 until 1936 the state production never reached the peak that it had obtained in 1846. From 1936 to 1945, however, production grew tremendously reaching a high of 370,260 tons in the latter year with a value of over one million dollars. The early part of this increase from 1936 to 1942, was brought on by the expansion of the chemical industry which depended on salt brine for its raw material. The great increase in production between 1942 and 1945 was made possible by the beginning of the West Virginia rock salt industry and the requirements of World War II.

In the early days salt was produced only for family consumption but as wells were drilled and the salt industry began this broadened out to include production for domestic and agricultural use. Since the beginning of the chemical industry based on salt as a raw material, its uses have multiplied rapidly and now include bleaches, soda ash, dyes, soap, textile processing, packing and curing of foods, dairy products, water treatment, metallurgy, insecticides, synthetic rubber, and others.

Summary and Conclusions

The salt industries of West Virginia have attained large proportions, and will increase further. The reserves of salt both as brine and as rock salt are large. Rock salt reserves under the northern counties are enormous, and their further development along the Ohio River is expected to play an even more important part in the chemical industries of West Virginia.

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Some Aspects of Mechanical Coal Cleaning in Utah

By CARL S. WESTERBERG*

Coal preparation practice and trends follow, among other factors, production trends in any given area. Considering an area the size of a state, some broad predictions may be made after a review of the annual production records. As this paper is concerned with coal cleaning in Utah, data on its production record are pertinent.

Table 1 shows the percentage relation of coal production in Utah to the national total as a single figure up to 1935 which includes all recorded production. From 1935 through 1947 these data are presented by years.

It is evident from these data that the production of Utah coal is ascending. The reason for this trend is industrial growth in the West resulting in a population shift which accounts for more people than the normal increase would supply together with Utah's relatively fortunate geographical location and its abundance of good-quality coal. Utah is also hopeful of supplying more coal in the future for West Coast power generation.[1]

Utah is not unique among coal-producing states in anticipating greater production in the future. *Coal Age* states, " . . . it is now evident that a billion-ton yearly production of anthracite and bituminous by 1960 is not impossible." At present it is about 610,000,000 tons, the all-time high in 1947 was approximately 687,803,000 tons.

In view of the trend outlined above, obviously more new mines will be required to produce the necessary tonnage. These in turn will require more mechanical cleaning capacity. Whether the required new plants will be built by present operators of mines and mechanical cleaning plants or by others now in the business of producing coal or expecting to enter it is of no consequence in this discussion. The fact is—they will be built.

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TP 2632 F. Discussion of this paper (2 copies) may be sent to *Transactions* AIME before Aug. 30, 1949. Manuscript received Jan. 28, 1949.

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[1] References are at the end of the paper.

Table 1 . . . Relation of Coal Production in Utah to National Total from 1935 through 1947

Year	Utah Production to National Total, Pct[a]	Utah Coal Mechanically Cleaned, Pct[b]	Utah Production in Thousands of Tons[c]
Total all years records exist to 1935	0.70	0.0	121,600
1935	0.79	0.0	2,947
1936	0.74	0.0	3,247
1937	0.86	0.0	3,810
1938	0.85	0.0	2,947
1939	0.83	9.1	3,285
1940	0.78	20.3	3,576
1941	0.79	22.1	4,077
1942	0.95	23.1	5,517
1943	1.13	18.7	6,666
1944	1.15	22.7	7,119
1945	1.16	23.5	6,679
1946	1.12	26.5	5,990
1947	1.18	24.4	7,429

[a] Calculated by author from U.S. Bureau of Mines data.
[b] Estimated by author. Certain installations are not considered such as Bradford breakers, a spiral chute cleaner, and one small air-sand plant.
[c] U.S. Bureau of Mines.

Other Factors Indicate Need for More Mechanical Cleaning-plant Capacity in Utah

At the present time, two of four metallurgical-coal-producing mines in Utah require that their output be mechanically cleaned. While the exact extent of coking-coal reserves in Utah has not been defined, the minable reserves are not considered to be as extensive as western heavy-industry would like. Therefore, it is necessary to recover all of this type of coal possible with whatever impurities must be taken with it. Thus, efficient iron and nonferrous ore reduction, requiring high-grade coke will need mechanical cleaning plants to produce clean coal from mine-run coal. The latter may contain 30 pct or more of extraneous impurities.

The national policy of conserving natural resources also requires that coal extracted from government-leased land be removed as completely as possible consistent with minability. This does not permit the past practice in private lands of detouring around local areas found to be difficult mining because of poor roof conditions or containing coal with considerable extraneous impurities such as bony bands or rock splits. The U. S. Geological Survey, charged with the administration of public lands, does not demand that a mechanical cleaning plant be erected to process coal from public lands. However, enforceable regulations in mining and completeness of extraction dictated by this agency may make such plants necessary if markets are to be found.

Industrial users of coal are growing more aware of the cost advantages of using mechanically cleaned coal. It is lower in ash and sulphur, moisture content and size consist are uniform, and ash-softening takes place within narrower temperature limits. In addition, the fallacy of paying high freight rates for long hauls for a relatively high percentage of noncombustible material becomes apparent upon analysis. For example, consider the movement of 100,000 tons of coal from the Carbon County, Utah district, to the Bay area of California. The present freight rate is $5.95 per ton plus a 4 cents per ton excise tax. A washed coal with a 2 pct lower ash content would result in a saving of $11,980 in freight on inert material alone. Heat from one typical Utah coal delivered to the Bay area in the raw state would cost 42.6 cents per million Btu. The heat from the same coal washed (2 pct less ash content) would cost 41.6 cents per million Btu. This saving expressed in dollars on a 100,000 ton movement would amount to $24,622. In addition, there are calculable savings to be realized in reduced ash handling with the use of washed coal and tangible but difficult-to-calculate savings from greater uniformity.

Domestic coal users, also prefer mechanically cleaned coal because its use results in trouble-free operation.

Competition with liquid and gas fuel makes it necessary to give the user the most heat and satisfaction for his money. With the trend of rising prices in coal, the producer must increase his prices to stay in business. The customer is obliged to pay the bill of course, but he can keep his cost of heat down by getting better value in purchases of coal. The operator must then, afford a better product through mechanical cleaning.

Thus, the factors that indicate more mechanical coal cleaning will be required in Utah are:

1. More coal will be produced.
2. The supply of coal for metallurgical purposes must be extended by mining and then cleaning the highest feasible portion of this type of coal.
3. The government policy of complete coal recovery from public lands may require mechanical cleaning of the coal mined.
4. Quality requirements by large users is more exacting.
5. Domestic users are more quality-conscious.
6. Competition with other forms of fuel requires that more heat be delivered per unit weight of coal.

Factors to Consider in Planning Mechanical Cleaning of Coal in Utah

The classical engineering approach to any mechanical cleaning problem, after the economics have been studied, is to conduct a washability study. This study, when it accurately represents the coal to be cleaned, gives the following information:

1. The size distribution or screen analysis, necessary to the designer in planning screening, conveying, and drying capacity.
2. The probable ash and sulphur content of the cleaned coal at any given specific gravity.
3. The percentage of coal that can be recovered as clean coal at the washing gravity selected.
4. The difficulty or ease with which the coal can be washed, that is, the probable efficiency of the separation.
5. The type and size of equipment that will be required to perform the necessary operations.

The economics of the proposed plant must then be reviewed in the light of information from this study.

Washing Characteristics of Coals Mechanically Cleaned in Utah

From an examination of the washability curves yielded by such studies shown in Fig 1 and 2 it may be generalized that Utah coals now cleaned mechanically do not present any very difficult problems for the equipment employed. It may also be assumed that mines to be opened in the future will yield coal with characteristics similar to those of one of the four shown.

In each of the coals represented, Curve *A* indicates the percentage of coal that will float at a given specific gravity. The ash and sulphur content (not shown) is generally plotted on an extension of this graph. By placing a straightedge across the graph, the percentage of recovery and ash and sulphur content of both the clean coal and rejects can be determined at any given specific gravity of separation.

Curve *B* on each graph is a convenient way to obtain some idea of how difficult the washing problem will be. The position of this curve is derived from Curve *A* and shows the amount of material in percentage included within 0.05 sp gr on either side (plus or minus) of the separating gravity. In each of the washability curves illustrated the corresponding coal is washed at approximately 1.50 sp gr. Table 2 shows what may be inferred from these graphs.

Table 2 . . . Washing Characteristics of Coals at 1.50 Sp Gr as Indicated in Fig 1 and 2

Coal	Indicated Recovery, Pct	0.05 Sp Gr	Ease of Separation
King mine	93	1.5	Very easy
Clear Creek	93	1.5	Very easy
Castle Gate	93	4.0	Moderately difficult
Sunnyside	94	3.0	Easy

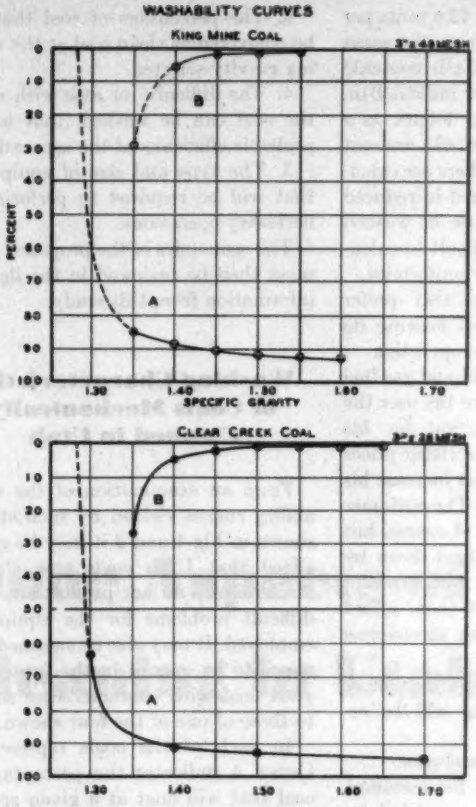


FIG 1—Washability curves. *A*, specific gravity curve; *B*, ± 0.05 sp gr distribution curve.

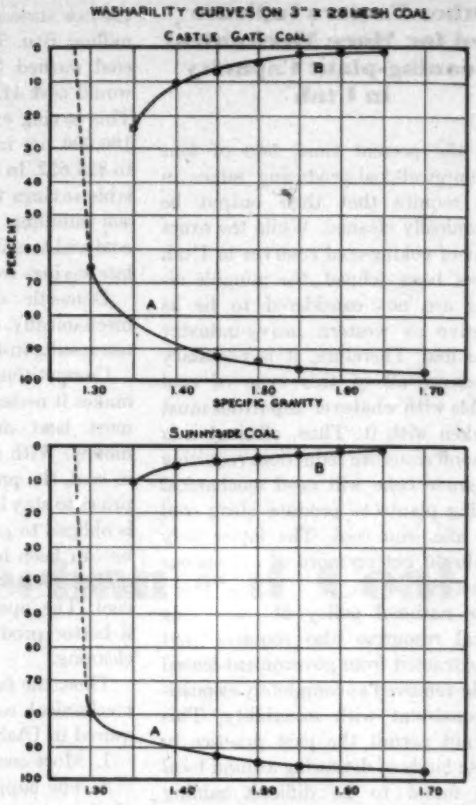


FIG 2—Washability curves on 3 in. by 28 mesh coal. *A*, specific gravity curve; *B*, ± 0.05 sp gr distribution curve.

The author has seen charts which assign descriptive terms to arbitrary numerical limits on the 0.05 sp gr curve. These are informative, but are not shown here because they are devised for eastern coals which are somewhat different than those illustrated and consequently may not apply. In other words, the terms "very easy," "easy," etc., as shown on Table 2 are relative.

These four coals are washed in three plants equipped with Baum-type jigs. All have five cells with two compartments and are pulsated by air at from 2 to 3 psi pressure. The rated capacity of each is about 250 tph and all are operated in excess of rating with results consistent with the varying character of the coals and the rate and continuity of feed.

Two of the plants are for the preparation of domestic and industrial fuel and the third is for metallurgical coal. Centrifugal drying is employed in all three plants on sizes below $\frac{3}{16}$ in. and in the two domestic and industrial coal plants, heat drying for the sizes below 1 in. is also used.

Fig 3 presents the approximate performance of these plants with respect to product quality and a comparison with the raw coal fed to the plant.

It will be noted that the limits of ash and sulphur content on the washed products are not wide, but better performance in this respect would be desirable. Unfortunately, extremely close control of the ash and sulphur content of the washed coal output cannot be realized without a uniform input. To ensure a uniform raw coal feed to a cleaning plant requires a large and suitable blending bin. It should have a capacity related to the daily average production of the mine with a minimum of about 800 tons of storage space to be effective. This bin must be compartmented and equipped with an arrangement to draw-off coal from all of the pockets at the same time. Such special bins have fairly wide acceptance in eastern metallurgical-coal-cleaning plants but are not generally used in cleaning plants processing domestic and industrial coal. However, this facility can be justified from another viewpoint.

A large surge capacity for raw coal makes the mining operation more efficient. With a surge-blending bin, moderate-size cleaning plants can prepare a constant but smaller flow of coal as compared with an oversize plant necessary to accept an intermittent flow with high peaks in the rate of input.

Thus by the use of surge-blending bins high-cost mining equipment may be used continuously and more profitably without the necessity of building more expensive additional cleaning capacity.

The Geneva Steel Co. in Utah employs such a blending bin though not in connection with a cleaning plant. This firm has evidently planned its operation on the assumption that it is better to have a uniform raw coal for its coking operations than a cleaning plant which may not be necessary at

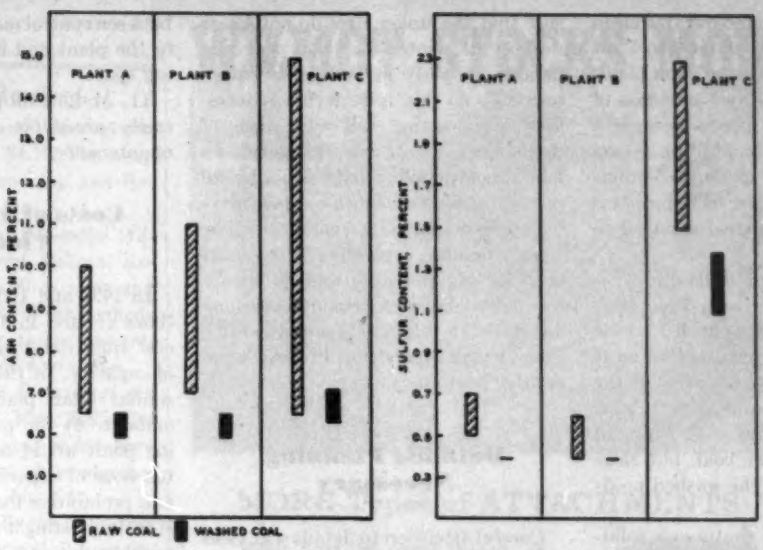


FIG 3—Approximate performance of three mechanical cleaning plants on representative Utah coals.

the present time. At any rate, it has the basic step completed when it is ready to employ mechanical cleaning. Meanwhile, this company is realizing the advantages gained in continuous mine operation.

A Cleaning Plant Byproduct

An interesting feature of the mechanical cleaning plant operated by the United States Fuel Co., at Hiawatha, Utah, is the recovery of fossil resin which occurs in the coal. This material, when pure, is useful in the paint and varnish industry. When the Combined Metals Reduction Co. perfected an economic method for concentrating free resin from coal,[2] an alert management at the Hiawatha property added facilities to skim off impure but concentrated resin from the circulating water circuit in the cleaning plant. This concentrate is sold to Combined Metals Reduction Co. for further processing. By this means a nuisance material is converted to a valuable byproduct. This free resin does not occur in sufficient quantities in coals mechanically cleaned in other Utah plants to warrant recovery.

Baum Jig-type Plants

Any western operator, considering the installations of mechanical cleaning facilities should study these existing plants because they are available, operate satisfactorily, and represent considerable thought, planning, and experience. Because water is required for operation, the operator should examine his own supply to be sure he can rely on at least 300 gpm during operating time. If, as is often the case in a semiarid location, water in this quantity is not available, he must turn to other processes.

Other Systems of Mechanical Coal Cleaning

Coal may be air cleaned by the use of air and air-sand combination, between the size ranges of from about 4 in. down to 48 mesh. However, thought must be given to adequately preparing the coal prior to cleaning. Recent eastern installations have shown that air systems are only as successful as are the drying and screening equipment ahead of the cleaning units. It is not overcautious to state that it is necessary to heat dry *all* coal before screening and air cleaning if reliable performance is expected.

Where precision washing is required, other types of washing equipment merit consideration. Recent perfection of heavy-density cleaning equipment permits very precise control of the washed product. In this system, heavy foreign matter is separated by gravity from coal by the use of a medium consisting of water and magnetite, sand, or other materials which have the effect of increasing the specific gravity of the water to any desired specific gravity from about 1.3 to 1.7. This system is inherently more precise than a system that depends upon stratification of material in a rising current of water as in the Baum jig, hydro-classifier, or launder. In fact, the heavy-density system yields almost a theoretical separation. There are two major objections to such a system, it will not clean coal much below ¼ in. by 0 in size, and the cost of installation and makeup media is relatively high. In the case of the sand system, maintenance is relatively costly. However, the system is justified in specific cases.

Recovery of Coal

The washability study, when gravity separations are made down to zero size, yields a percentage of possible recovery based on the idea that all the coal down to zero size, floating at a given specific gravity, is recoverable. In practice, the approach to this ultimate recovery is only as close as the equipment provided will allow. Coal below minus 28 mesh in size becomes increasingly harder, that is, more costly to recover. Until about a year ago it was not possible to recover clean coal much below 48 mesh in size because the equipment to do so

did not exist. This unrecoverable clean coal represented from about 2 to 5 pct of the raw feed to a preparation plant. The accumulation of vast amounts of "slurry" in nearby ponds became a costly nuisance, and in addition, represented unrecovered dollars. Various devices have been used to reduce this loss, none of them a real solution to the problem.

Because of handling difficulties it is impossible, or prohibitively expensive, to recover this slurry as such by heat drying alone. Some operators found it possible to bypass some portion of the ¼ in. by 0 raw feed and remix it with the washed portions of coal. This did reduce the loss of fine coal, but close control of quality in the washed product was lost.

Now available is a continuous solid-bowl centrifuge which appears to be able to dewater coal down to almost zero in size. Application of this device may solve the fine-coal-loss problem in wet cleaning plants. The Marianna Plant of the Bethlehem Steel Co. employs several units of this type and is said to operate in completely "closed circuit," that is, it has no loss of fine clean coal. Other plants now under construction will employ these units.

The Utah Fuel Co. has completed a preliminary study of the cyclone thickener[3] as a possible partial solution to this problem. Application of this device in connection with heat drying, it is hoped, will help to solve the fine coal recovery problem in its Utah preparation plants. It has been tried elsewhere with doubtful success, but it is believed that further refinements and a better understanding of its application will make it a valuable tool in fine coal recovery.

Another factor to be weighed carefully is how far to go in the matter of heat drying. In preparing domestic and industrial coal, it has been sufficient to remove enough surface moisture to ensure that the stoker sizes do not freeze during the winter and that this size handles properly in automatic equipment. To do this, heat drying is necessary after taking full advantage of mechanical dewatering equipment. In long-range planning it is advisable to provide space for additional heat drying equipment for the coal sizes below 1 in. because expanding Utah coal markets will probably include a substantial tonnage movement over long distances. In this case, a producer with extra drying capacity will have a competitive advantage.

Detailed Planning Necessary

Careful attention to details will yield large dividends in efficient plant operation when a new plant begins operation. Some of these are:

1. Provision for adequate equipment to move refuse and a space to dispose of it.
2. A good system for oil-treating domestic stoker coal.
3. A good heating system for the preparation plant.
4. An adequate supply of repair parts in stock and readily available.
5. Lockers for special tools and equipment within the preparation plant.
6. Plenty of artificial lighting within the plant and in the railroad car-loading and storage area.
7. A good control laboratory supervised by a trained technician with sufficient help to carry out an adequate control program.
8. Provision for inspection maintenance at regular periods every operating day.
9. Conveniently located power, compressed air and welding current outlets within the plant.
10. A good communication system between control men and various points in the plant and the railroad car-loading space.
11. Making all portions of the plant easily accessible for inspection and maintenance.

Costs of Mechanical Cleaning

In 1938 and 1939 a plant similar to those erected in Utah in that period cost approximately $1000 per ton-hour of capacity. In 1942 and 1943 another similar Utah plant cost double this amount. At the present time a cleaning plant would cost about $4000 per ton-hour of capacity. This cost is high and prohibitive for smaller operations. It is interesting to speculate on what could be done by organizing a cleaning plant company to serve a group of moderate and small sized operations in the same district.

Summary

The foregoing presents some of the reasons why coal mechanical cleaning capacity in Utah may be expected to increase. To meet the need for increased capacity for coal cleaning in Utah, one approach to the selection of equipment is outlined with mention of some of the special problems that may be encountered.

References

1. C. P. Heiner: The Economics of Coal for West Coast Power Generation. Presented at Annual Meeting AIME, San Francisco, Feb. 1949.
2. Ernest Klepetko: Recovery of Resin from Utah Coal. *Min. Tech.* and *Coal Tech.* (May 1947) TP 2166: *Trans.* AIME (1947) 173, 410; (1948) 177, 433.
3. H. F. Yancey and M. R. Geer: The Cyclone as a Thickener of Coal Slurry. *Coal Tech.* (Feb. 1948) TP 2351; *Trans.* AIME (1948) 177, 262.

Book Reviews

New Books Received

Metal Magic. By Isaac F. Marcosson. Received April 15. $4.50. The story of the American Smelting and Refining Co.

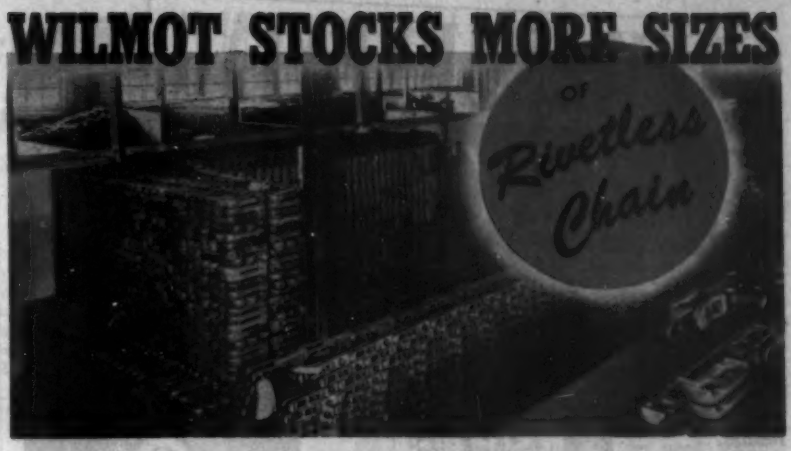
Mine Accounting and Financial Administration. By Frank Willcox. Received April 8. $7.50. A clear and comprehensive study of the methods of setting up and operating accounting systems for mine operations.

Annual Report of the Director of the Mint. Received in May. $.35. Report for the fiscal year ended June 30, 1948, and report on production of precious metals for 1947.

Copper in California. By the California Department of Natural Resources, and co-operating agencies. Received May 13. Detailed reports on the foothill copper belt, the marketing, and metallurgy of complex ores in California, and a tabulation of copper properties.

Principles of Structural Geology. By C. M. Nevin. Received May 12. $6. Discusses the earth's deformations as simply as possible.

(*Continued on p.* 34, Sect. 1)



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(*Continued from p. 33*)

Iron Ore Statistics

A slim, 38-page booklet from The M. A. Hanna Co.—"Analyses, Iron Ores, 1949," provides a handy pocket-size reference to the company's operations in that field. Tables of prices, rail freight rates shipments, stockpiles, and consumption of iron ore, many dating from before the turn of the century, and including the latest figures, will consume very little desk, pocket, or library space and easily prove its utility value to busy buyers.

California Iron for Western Industries

Iron Resources of California. Bull. 129, State of California, Dept. of Natural Resources, San Francisco 1948. 304 p.

Never before has such a complete bulletin been issued covering in detail descriptive matter concerning all of the known iron-ore deposits of importance in California. Warren T. Hannum, director of the department of natural resources, makes this truthful statement in the volume's letter of transmittal to Governor Warren. A glance at the table of contents bears out his words; the Eagle Mountains district, Iron Mountain and Iron King, Old Dad Mountain, Cave Canyon, are some of the areas discussed, illustrated by excellent geologic maps and sections. With iron reserves of California estimated at between 100 and 150 million long tons, an increase in operation in that state may surely be anticipated.

Yagoda on Radioactive Measurements

Radioactive Measurements with Nuclear Emulsions. Herman Yagoda. John Wiley & Sons, New York, Chapman & Hall, London. 1949. 356 p. $5.

REVIEWED BY RALPH J. HOLMES

Doctor Yagoda, senior physical chemist at the National Institute of Health, is well known to mineralogists and chemists for his numerous papers on the methods employed in the study of radioactive materials. His first book in this field is concerned with the techniques involved in the use of special photographic emulsions which Yagoda has designated by the term "nuclear emulsions" since they are designed specifically for the "study of the mechanism of nuclear reactions." In the early years of the study of radioactivity the photographic emulsion played a large part in the advancement of that branch of science but was later overshadowed by electronic devices. Now it has again come into its own as a result of the vast improvement in emulsion preparation and the fact that these improved "nuclear emulsions" are now commercially available.

Applications of the method to many fields including mineralogy, chemistry, biology, medicine, metallurgy, and nuclear physics are considered. Although attention is devoted to the theoretical basis of the effects obtained, the great value of the book lies in the detailed discussion of the methods and techniques, which should prove exceedingly helpful to all who are concerned with the detection and identification of radioactive materials.

The book is well illustrated with carefully chosen drawings of apparatus, graphs, and reproductions of the photographic results of the techniques described. An extensive bibliography and careful documentation of statements appear at the end.

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SALES REPRESENTATIVES, preferably 25-35, college education or equivalent experience in technical field, preferably chemistry or metallurgy, with some previous sales experience. Must be willing to travel. $3600-$4800, plus travel expenses. Headquarters, northern New Jersey. Y1976.

MINING ENGINEER, with geological training or mining geologist who is recent graduate, to supervise drilling, sampling, mine surveying, and perform office work on open-pit mine maps and sections, east Texas. $3300-$3700, depending on experience. Y2040S.

FIELD MEN, preferably mining geology graduates, or geophysical surveys. Must have magnetic and electrical experience on mining projects. Considerable traveling. United States and Canada. Y2232.

MINING ENGINEER, preferably single, at least two or three years' experience on underground engineering work including mapping, to do engineering work, keep maps up to date and assist in monthly reports from the property. $3600 to start, plus room, board, transportation. Central America. Y2291.

ENGINEERS. (a) Mining Superintendent, 35-45, at least five years' supervisory experience including mine development work for feldspar, tin and gold project. $6000-$7200. (b) Chemical Assayer, some metallurgical accounting experience, to take charge of sampling and laboratory analyses of mine ores. $4200. South Dakota. Y2299C.

CHIEF ENGINEER, 35-45, to take charge of all maintenance and mining operations for several widely scattered coal mines. Must have previous coal mining experience. $8000-$12,000. South. Y2304.

MINE MANAGER, mining graduate, to take charge of mining and milling operations of feldspar development. Must have had previous feldspar experience. Small operation. Salary open. East. Y2319.

MINE SUPERINTENDENT, 35-45, mining graduate, with underground experience as surveyor, foreman, assistant superintendent, and some milling experience, to supervise production of metal mine. $7200-$8400. East. Y2456.

MINE SURVEYOR, experienced in underground and map work. $4200 plus all expenses. Saudi Arabia. Y2478.

MINING ENGINEER, graduate, to instruct mine surveying, mining and prospecting, elementary mineralogy, mineral dressing laboratory. Prefer men with experience in West; for Pacific Coast university. Position starts September 15, 1949. Write giving full experience record, education, etc. Y2479S.

FIELD ENGINEER, mining graduate, with stripping or other earth-moving experience, to supervise and lay out shovel and other excavating schedules, etc. $3600-$4200. West Virginia. Y2519.

STRATIGRAPHER, with Ph.D., who has specialized in stratigraphy, to teach historical geology. Salary, up to $4500 for nine months, depending on experience. Missouri. Y2524.

MEN AVAILABLE

ORE-DRESSING METALLURGIST, B.S., E.M., 30, married, one child. Eight years' varied experience, research, testing and production; flotation, gravity concentration, leaching; precious metals, rare metals, base metals. Supervisory positions held. Desires responsible position operations, research, teaching. Presently employed, available 2 to 4 weeks' notice. Prefers U. S. or Canada. M-434.

ECONOMIC GEOLOGIST, M.S., 41, graduate well-known iron school, good training ferrous metallurgy, seeks connection (preferably salary-participating interest basis) organization interested long range exploration, examination, development iron, chrome, manganese ores.

(Continued on p. 36)

Book Reviews

(Continued from p. 34)

A Landmark is Revised

Physical Geology. Third Edition. By C. R. Longwell, A. Knopf, and R. F. Flint. John Wiley & Sons, Inc., New York City. 1948. 602 p. $5.

This standard college textbook on physical geology is as durable as the geologic time with which it deals so well. It has been in use for sixteen years, and is now on the book lists of 135 colleges and universities in this nation and Canada.

The authors, viewing textbooks as "aids in teaching, to be used with desired flexibility," have apparently attained their goal of presenting the basic outlines of a "vast and unfamiliar field of knowledge" to oft-confused students.

A new Chapter Two has been added, dealing chiefly with the concept of isostatic balance in relation to the deformation of the Earth's crust, and much attention has been given to improving the illustrations, which now number 365.

California's Copper

Copper in California. State of California, Department of Natural Resources, Division of Mines, Ferry Bldg., San Francisco. 1949. 429 p. 61 maps in pocket.

This book was prepared by six authors, and with the co-operation of the USGS, the Bureau of Mines, and Stanford University's department of mining. It deals chiefly with the rich 250-mile-long belt of copper and zinc mineralization along the western slope of the Sierra Nevada, which includes parts of eleven California counties. Part I of the book gives detailed reports of deposits in eight counties in that copper belt, which had produced, between the Civil War and 1944, 195 million pounds of copper and over 30 million pounds of lead.

Part II describes the marketing and metallurgy of the state's complex ores, and covers, in some detail, the milling of complex ores by differential flotation methods. It considers the history of, markets for, and competitive position of California's base-metals. Part III is a detailed tabulation of copper properties, to accompany an economic mineral map of California.

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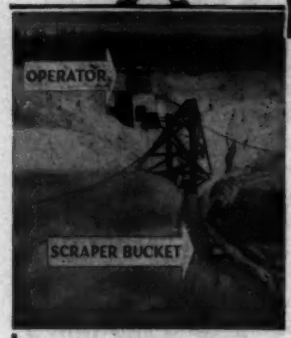

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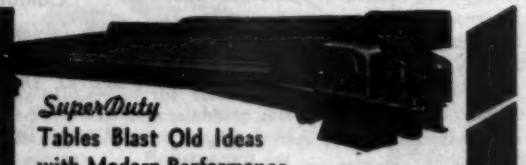

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(*Continued from p. 35, Sect. 1*)

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CERAMIC ENGINEER, 40, married, B.S. degree in ceramic engineering 1933. Plant engineer on production of chrome, magnesite and silica refractories; plant design and estimating Portland Cement and heavy clay product plants; foreign and domestic field geology exploration on ceramic raw materials; developed industrial economic survey reports; office administrative and engineering experience. Available immediately. Prefers West Coast or foreign. M-443-495-E-7-San Francisco.

JUNIOR ENGINEER, 28, veteran, single, B.S. mining engineering (metallurgy option). Nineteen months' experience milling and fire assaying. Desires position with opportunity to get mining experience. Available 30 days. Prefers United States. M-444.

MANUFACTURERS NEWS • *Equipment — Bulletins — Personals*

Paving Breaker

Intended for fast demolition work and for use wherever footing is treacherous, a new paving breaker, weighing only 38 pounds, has been added to the Gardner-Denver line. The manufacturer states that, although light in weight, the B37 is exceptionally sturdy and built for years of hard work.

Better Mine Safety

Mobility is the keynote of the latest developments in organized mine rescue and instructional work. A new, effective means of bringing to employees at every mine the latest in safety practices with complete equipment for demonstrations and training is the Mine Safety Appliances Mobile Safety Station. M.S.A. Mobile Safety Stations are equipped according to specifications with a complete range of safety apparatus for rescue work, laboratory testing, maintenance, instruction, and first aid.

Atomic Blinker

A small portable instrument for the detection of radioactivity called the RCL Atomic Blinker has been manufactured by Radiation Counter Laboratories, Inc., Chicago, Ill. The "Blinker" contains a Geiger-Mueller countertube. It uses 300 volts from batteries contained within the instrument, and radioactivity may be detected by use of ear phones or by watching the blinking of the light which is on top of the instrument. Among the applications are prospecting for radioactive minerals, radioactive contamination surveys, and student and public radioactivity demonstrations.

Continuous Weighing

The Sintering Machinery Corp., 70 Pine St., New York, original patentors of the "tilting wheel and disc" mechanical weight integrator, announce a "unit type" belt conveyor scale which is assembled and shipped as a complete unit, requiring fewer than a dozen bolts for its complete installation. This Transportometer can be installed on any existing horizontal, inclined or declined belt conveyor of any width or speed, to automatically and continuously weigh, indicate and totalize the tonnage at any rate up to 2000 tons per hour. Transportometers are available for automatically regulating preceding feeder conveyors, rotary valves, etc., and can be provided with remote mounted chart recorders, tonnage indicators, duplicate totalizers and predetermined batch counters.

Heavy-Duty Dump Bodies and Hoists

Designated as the "300" Series of dump bodies and the No. 827 Iso-Draulic Roll-A-Lift Hoist, these new additions to the Perfection line are designed for the most rugged type of service. According to the manufacturer, the "300" Series bodies are made in styles for every purpose. They are carefully constructed of 8-gauge high-resistant sheet steel, heavily braced at all points of stress. Body understructure is made of 4-in. I-Beam cross-bolsters and 5-in. I-Beam longitudinal sills, all securely welded together and welded to the body. The No. 827 hoist (shown in the lower portion of the cut) is claimed by Perfection to be their own Iso-Draulic Roll-A-Lift design for use with heavy-duty bodies. For complete information write to The Perfection Steel Body Co., Galion, Ohio.

New Electric Shovel

A new simplified Diesel electric shovel is made possible by P&H's

"Magnetorque" hoist drive which entirely eliminates the hoist generator, hoist motor, slip friction clutches, and other mechanical devices usually involved in the hoist train. The cushioning characteristic of the "Magnetorque" drive, combined with that of the electrical power system of the crowd and swing, relieves the Diesel engine of the severe "pull down" in speed common to friction type shovels. The heavy-duty Diesel engine easily maintains a steady flow of power under all loads.

Alnico Plate Magnet

Completely automatic separation of magnetic and nonmagnetic materials with an Alnico plate magnet has been achieved with the self-cleaning permaplate recently developed by Dings Magnetic Separator Co. of Milwaukee, according to the manufacturer. This permanent nonelectric magnet unit is designed to provide moderately priced automatic protection for crushers, grinders, pulverizers, stokers and other machinery susceptible to tramp iron damage. It can be installed over conveyor belts, spouts or chutes.

(*Continued on p. 38*)

(Continued from p. 37)

News

The Texas Co. has set up a single cylinder aircraft test engine with an unusual set of control instruments, in its Beacon, N. Y., laboratories, to establish the anti-knocking qualities of aircraft engine fuels. A unique gadget called the automatic octane blender has been devised to check new fuels, and a new kind of intake air temperature control enables the engineer to determine fuel performance rapidly under varying temperatures.

To present its new line of Diesel engines and bring the facts of Diesel economy directly to truck operators, Mack Trucks has launched a unique mobile exhibit on a five-months' nationwide tour. The company's three new Diesel engines, the END 457, 510 and 672, are housed in an eye-catching green, yellow and red semi-trailer pulled by a Mack diesel-powered tractor. A. G. Crockett, director of market research for Mack, will be in charge of the exhibit.

On July 17, members of The Thew Shovel Co., Lorain, Ohio, will celebrate their 50th Anniversary as a corporation. The first full revolving shovel—a Thew—was developed in 1895. Thew full revolving steam shovels soon found their way into mines, brick plants, highway jobs, building excavations and related jobs. New uses brought new requirements and led to Thew's development of a single-motor electric shovel in 1903 and one of the earliest gasoline powered shovels in 1914. Today Thew operates five plants in Ohio, two in Lorain, two in Elyria, and one in Bucyrus, with all its engineering and production facilities concentrated solely on the manufacture of power shovels and cranes.

Complete electric hoist drive equipment, including one of the most powerful hoist motors in the country, is being built by General Electric for shipment next fall to the Anaconda Copper Mining Co. at Butte, Mont. The 600-volt d-c motor, rated 3000 hp. at 60 rpm., will drive an ore hoist at the Kelley Shaft, an important part of Anaconda's $25,000,000 "Greater Butte Project" for the recovery of low-grade copper ore by the caving method. G-E engineers say that the elec-

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Personals

J. F. O'Brien has been appointed general sales manager of the Vulcan Iron Works of Wilkes-Barre, Pa., and C. A. Netter as general purchasing agent.

Robert E. Marshall has been elected secretary of the Worthington Pump and Machinery Corp., Harrison, N. J.

Chester H. Sanderson, who has been employed for over twenty years in Mine Safety Appliances Co.'s direct mail, display, and advertising departments, has been appointed advertising manager.

The American Cyanamid Co. announces the appointment of *C. F. Bonnet* as production manager of its Industrial Chemical Division, and *G. W. Russell* as assistant sales manager of the same division.

Ronald E. Griffiths, for three years supervisor of the American Steel & Wire Co. research laboratory in Cleveland, is now assistant director of research for the company.

Jack B. Bond has been appointed district manager of the Central Territory for the crusher and process machinery division of Nordberg Mfg. Co., Milwaukee.

T. F. Rose, Cincinnati branch manager of The Timken Roller Bearing Company's service sales division, is now manager of Timken Roller Bearing Service and Sales Limited, Toronto, Ont., Canada.

Chester F. Conner is manager of the industrial products sales department of the Industrial and General Products Division of The B. F. Goodrich Co.

General Cable Corp. of New York recently elected three new vice-presidents: *Samuel A. Smith*, in charge of research and development; *Oscar G. Garner*, in charge of manufacturing; *Allen D. Pettee*, in charge of product engineering.

Dale Hagenbook has been appointed chief engineer of the *Goodman Mfg. Co.* He joined the company in 1937 and has served as assistant chief engineer to *W. W. Sloane* since 1940. Mr. Sloane is now vice-president in charge of engineering.

XUM

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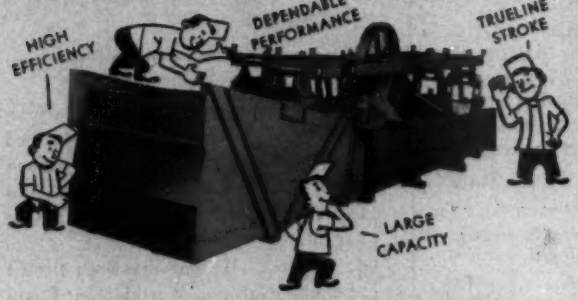

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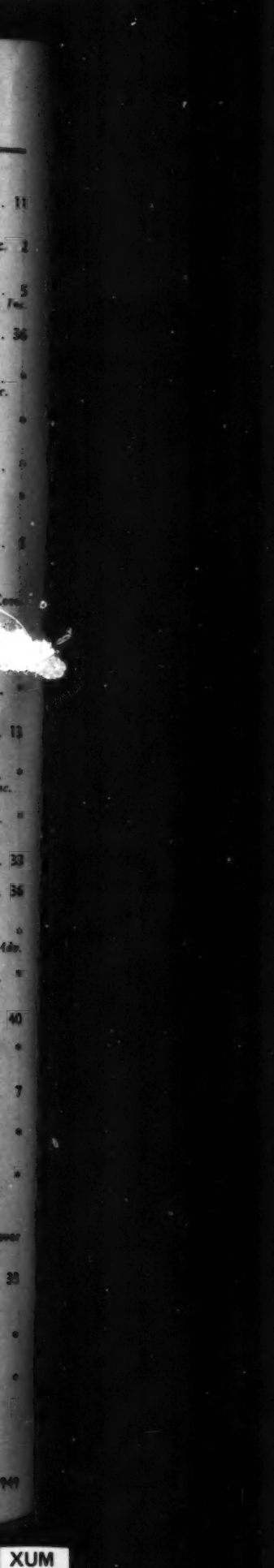
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